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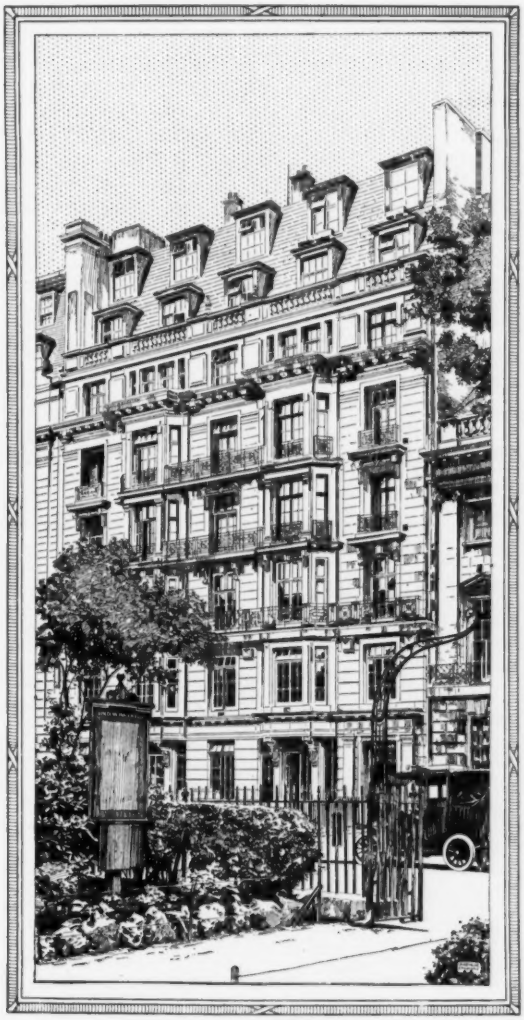

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ENGLISH ELECTRIC
MUSEUM

The British Empire Exhibition—General View of the English Electric Company's Stand.

The English Electric Journal

Vol. III. No. 1 JANUARY, 1925 One Shilling

CONTENTS.

PAGE

"English Electric" Products at the British Empire Exhibition - - - - - - 5

Arthur's Pass Tunnel Electrification, New Zealand - 44

New Double Drive for a Reversing Two-High Rolling Mill - - - - - - 56

All Communications respecting Editorial Contents should be addressed to The Editor, The English Electric Journal, Queen's House, Kingsway, London, W.C.2.

EDITORIAL.

The British Empire Exhibition has now closed its doors, and we think that in this number of the Journal it will be appropriate to give illustrated descriptions of some of our exhibits. By this means we hope to indicate to readers overseas or in this country who were unable to visit Wembley, the full range of our manufactures, and at the same time to provide a permanent record for those who wish to refresh their recollections of our exhibits. As a general rule we have devoted little space to standard productions or to those previously dealt with in these pages, but have written more fully where the novelty of the subject matter has justified it.

While referring to those from abroad who have visited us at Wembley, we are glad to take this opportunity of expressing the pleasure it has given us to meet so many of them this year. Messrs. Dick, Kerr & Co., The Phœnix Dynamo Manufacturing Co., Siemens Brothers Dynamo Works, and Willans and Robinson—all now merged in The English Electric Company — had foreign connections extending over many years, and the Exhibition has afforded our staff welcome opportunities of renewing old friendships.

If we turn now to review the exhibits described in the following pages, the first perhaps in interest to many visitors from abroad were those of hydro-electric plant. They formed the most important water turbine exhibit ever shown in this country, and established, what had previously not been generally appreciated, that we, in

this country, have manufactured turbines of the largest sizes and of the latest designs in this class of plant. The hydro-electric field is of great importance, and The English Electric Company is now in a position to meet the demand from all parts of the world. Of the hydraulic exhibits, perhaps the most interesting has been the large impulse wheel with its special governing device that gives, when required, an almost instantaneous dispersal of the full water jet that issues from the nozzle. The design of the cylindrical balanced main valve has also attracted much attention; firstly, on account of the accessibility of its working parts and the small space required for dismantling, and secondly, because the final closing of the valve can be effected very gradually and "slam-shutting" absolutely prevented.

The "English Electric" steam turbine and rotary converter plants have been in daily service in the Exhibition Power Station, which was very well arranged for inspection by visitors, while on the Company's stand the working model of the Fullagar engine has been of great interest to many engineers. In effect this type of engine increases the useful range of the Diesel engine up to sizes of 3,000 H.P. or more, and the possibility of a stand-by unit of this capacity, that can be started up from cold in 60 seconds, has appealed to all who have charge of large power undertakings.

Traction work has been represented by samples of railway motors as well as by our well-known camshaft control, and in the latter part of this Journal we give a description of the complete railway electrification that we have carried out for the Arthur's Pass Tunnel in New Zealand. This contract included steam turbines and all generating station plant, in addition to the overhead equipment of the line, and a number of locomotives. This article will, we hope, be of special interest as being descriptive of a complete railway electrification that is proving of the greatest benefit to the districts that it serves.

We include short descriptions of the experimental transverter and of our aeroplane and seaplane manufactures, also descriptions of some industrial applications of electricity, though of these it has only been possible, on account of the limited space at our disposal, to take a few selected instances. In connection with industrial applications perhaps the greatest interest has been shown in transformers and switchgear and in our apparatus for improving power factor, which includes not only synchronous motors that start as induction motors and are self-synchronising, but also the phase advancer, which is a small separate device for connecting in the rotor circuits of an induction motor. This device can be applied to existing motors when improvement of their power factor is desired.

In connection with industrial work, we would draw attention to a short article at the end of the Journal in which is described a new method of driving large reversing rolling mills, which has been tried with very satisfactory results. By the use of this method the pinions and pinion housings usually associated with such a mill are eliminated and many important advantages in operation secured, with a reduction in running costs.

"English Electric" Products at the British Empire Exhibition.

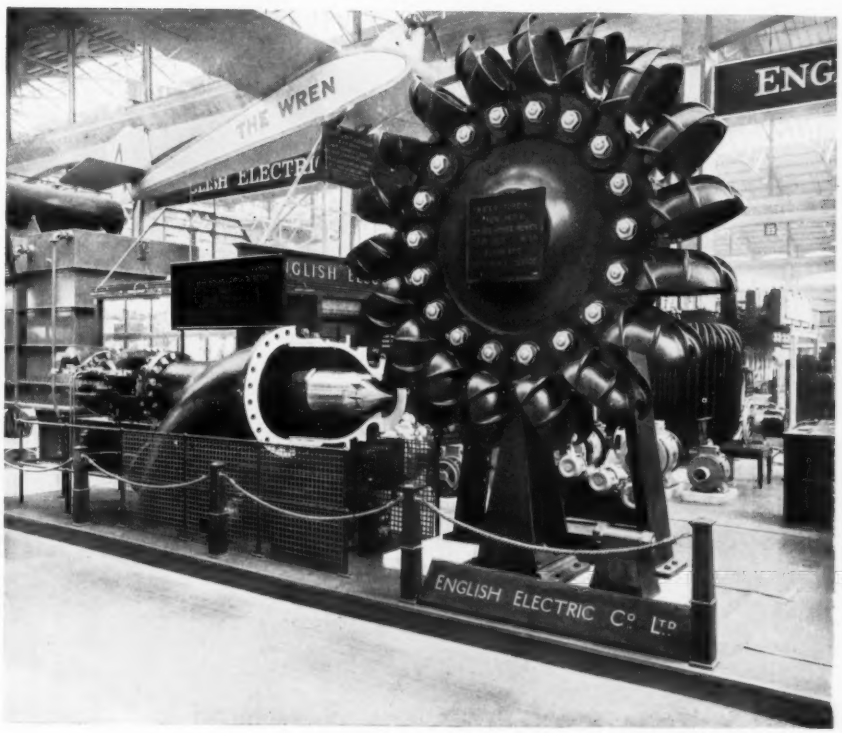


FIG. 1. THE 15,000 H.P. IMPULSE WATER TURBINE EXHIBIT.

HYDRO-ELECTRIC PLANT.

The English Electric Company has supplied or has in course of manufacture in its shops hydraulic units totalling nearly 300,000 H.P. of maximum output. In most cases the contracts include the turbine, electrical generator and their auxiliary apparatus, and it is without doubt a distinct advantage to our clients that we can supply plants of this kind complete in every detail.

Some of the units are not only the largest so far constructed in this country, but rank among the most interesting in the whole field of hydro-electric supply.

Among the most important examples of this work which we showed on our stand were a replica of the bronze runner for a 25,000 H.P. Reaction Turbine recently shipped to South America, a replica of the wheel, jet and governing apparatus for 15,000 H.P. and 30,000 H.P. Impulse Turbines, and a sectional model of the "English Electric" Balanced Valve.

The Reaction Turbine Runner is of considerable technical interest, and presents an accurate representation of the original bronze runner since it was cast from the same pattern, but in iron instead of bronze. At a later date, we shall publish a complete description of this interesting plant, and at present, therefore, we restrict ourselves to drawing attention to a few of the main features.

The set is designed for an output of 20,500 K.V.A. at 6,600 volts when running at 600 R.P.M. under a head of 600 ft. (195 m.), and in meeting these conditions many important technical problems had to be solved.

The runner, for instance, constitutes a record for output in proportion to size, in view of its discharge of about 400 cubic feet per second at full load, and its speed of 600 R.P.M. Owing to the high head it is necessary to keep the clearances between the runner and the surrounding parts within very small limits, since otherwise there would be an undue loss of water and consequent reduction of efficiency. Special care had also to be taken in designing the spiral casing in order to obtain adequate strength for the head in question, and it is constructed in cast steel having a thickness of $1\frac{3}{4}$ ins. It is further stiffened by a number of rods which connect the two end faces. The method of securing these rods is such as to avoid adding to the stresses due to the water, and consists in forming the screw-threads in the two sides of the casing and on the two ends of each rod, so that they are portions of one and the same thread.

FIG. 2. REPLICA OF BRONZE RUNNER FOR 25,000 H.P. REACTION TURBINE.

The complete set is mounted upon a single massive bedplate, and the main bearing between the turbine and alternator is braced to the turbine casing, near the central plane, by substantial bolts so as to render the whole unit perfectly rigid. Bronze has been used not only for the runner, but also for lining the discharge taper piece with a view to avoiding corrosion, and for the same reason the suction bend has been electrically insulated by special packing at the joints.

The governing apparatus is of our most recent design, and embodies double compensation, adjustment of the speed variation, hand and electrical speed adjustment and an automatic safety device for shutting down independently of the main centrifugal governor in the event of the governor belt breaking or runaway occurring. The oil pressure is

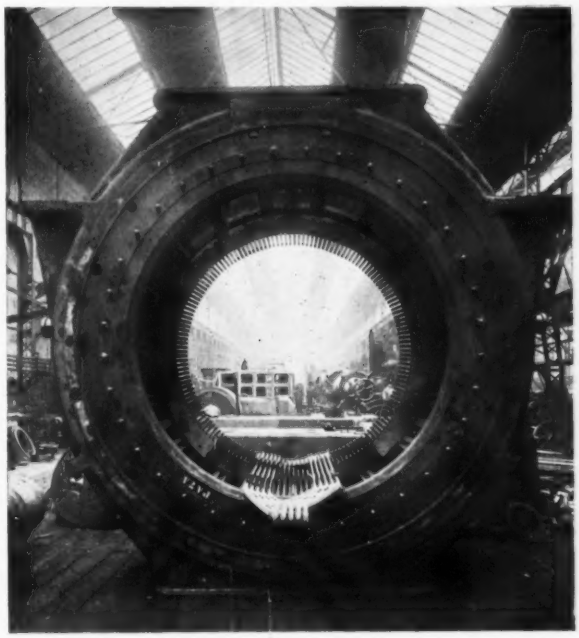


FIG. 3. STATOR FRAME OF ALTERNATOR FOR 25,000 H.P. WATER TURBINE SET.

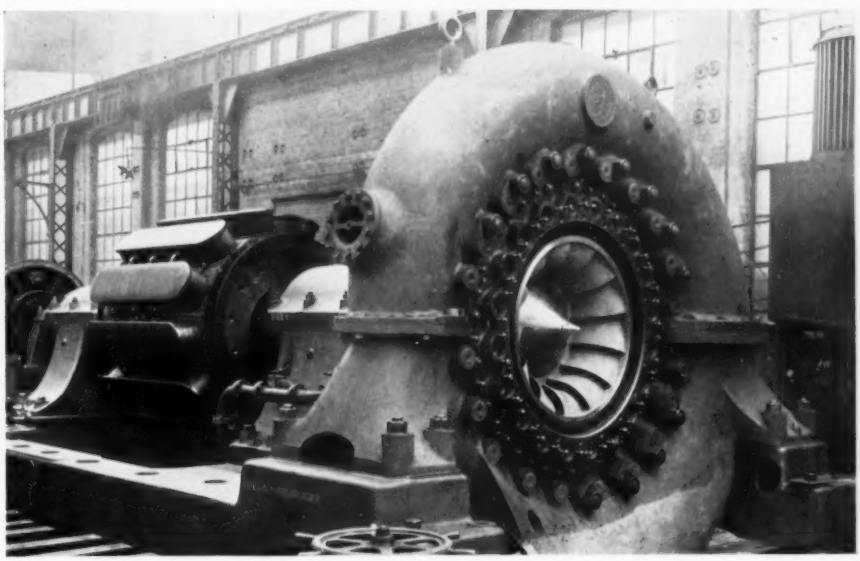


FIG. 4. 25,000 H.P. WATER TURBINE AND ALTERNATOR PARTIALLY ERECTED.

obtained from a rotary pump driven by an independent turbine of the impulse type. Figs. 3 and 4 show views of the turbine and alternator partly erected.

Another important accessory fitted to this turbine is the relief valve, which is controlled by the governor in such a way that it discharges the whole of the water shut off from the turbine when quick closing of the gate apparatus takes place. The chief feature of this valve lies in the use of oil pressure for operating it. It is fitted with dashpot, distributing valve and return motion gear, and designed with a special diffusing device to distribute the discharged water and avoid the impact of the whole mass on a small area.

The Impulse Wheel exhibit, Fig. 1, is of special interest in that it is a full size working model of the Governor Gear for the 15,000 H.P. Water Turbine which was fully described in the last number of the Journal. At the same time, the exhibit represents the working portion of one half of a Twin Impulse Turbine of 30,000 H.P.; five such sets are now under construction. The model wheel, representing cast steel to a total weight of 7 tons, has a wooden disc with aluminium buckets; the buckets are attached to the disc by our patented single bolt fastening, in this case the genuine article, and a complete spare fastening was shown separately.

In order to demonstrate the principle of the Seewer Patented Governing Device, the front half of the nozzle bend had been cut away so as fully to expose the spear, and a small electrically-driven oil pump was installed under the bend to provide the requisite operating pressure. As the primary means of actuation, the centrifugal governor would have been impracticable and unsuitable and in its place a hand lever was fitted by means of which the governing process could be imitated. Fig. 6 shows the nozzle in the full open position corresponding to the normal cylindrical jet striking the buckets with an impact of 30 tons. The radial guide vanes which can be just seen in the photograph, surrounding the spear, serve the double purpose of rectifying the water stream lines and also of transmitting to the exterior nozzle casting the forces which arise when the dispersing blades are projected into the jet under the action of the governor. In the exhibit these blades were pushed forward by operating a hand lever at the rear, when they assume a position corresponding to Fig. 8. This is the first effective movement which occurs when load is taken off the turbine and its speed rises; the centrifugal governor actuates a distributing valve which controls the admission of pressure oil to the servo-motor on the spindle which moves the blades. In our exhibit, the blades are pushed forward by hand, after which the subsequent operation is performed by oil pressure in the following manner. Referring to Fig. 5, the spindle of the blade operating lever carries a crank which is connected to rod 4 of the distributing valve of the spear servo-motor, so that this rod moves outward in the same direction as the blades and causes pressure oil to be admitted to the spear servo-motor; the spear is thus pushed forward so as slowly to follow the blades and close the jet

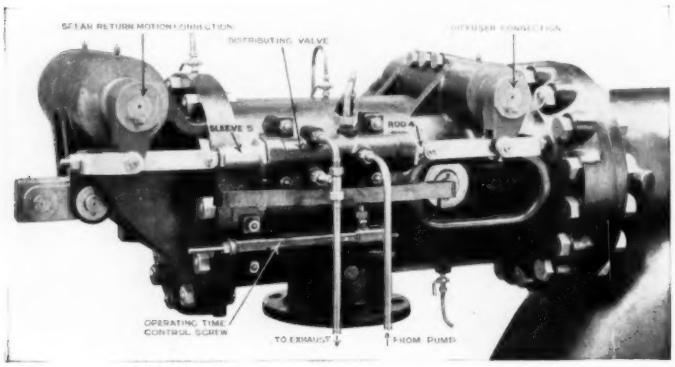


FIG. 5. GOVERNING MECHANISM ON IMPULSE WHEEL EXHIBIT.

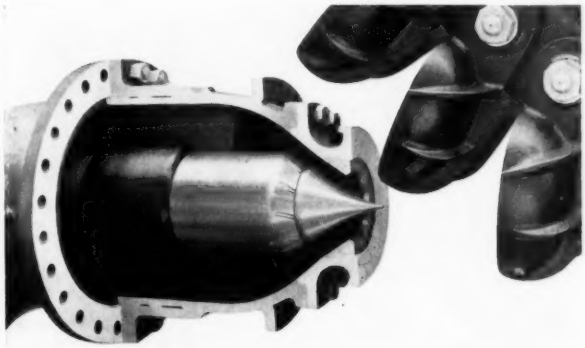


FIG. 6. SPEAR AND DIFFUSER IN NORMAL POSITION.

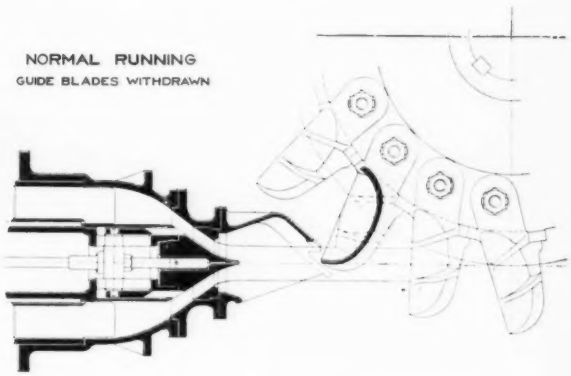


FIG. 7. DIAGRAM SHOWING PATH OF JET CORRESPONDING TO FIG. 6.

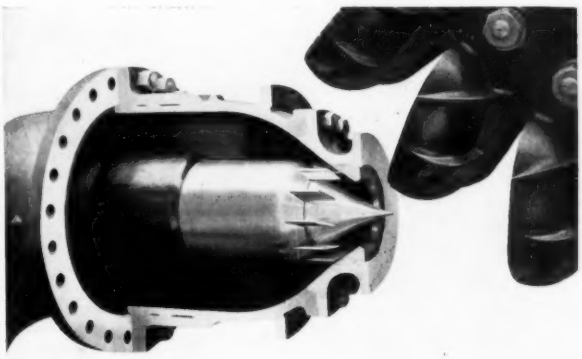


FIG. 8. DIFFUSER BLADES PROJECTED, FOLLOWING AN INCREASE IN SPEED.

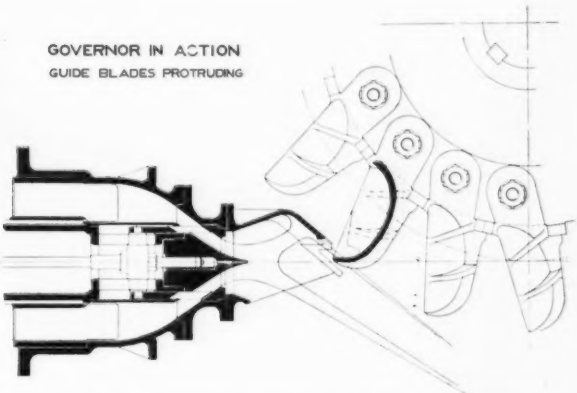


FIG. 9. DIAGRAM SHOWING DISPERSAL OF JET CORRESPONDING TO FIG. 8.

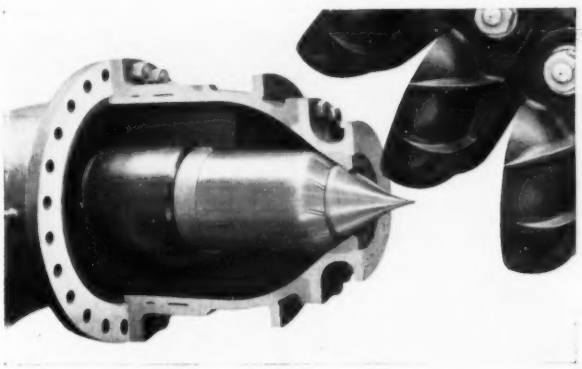


FIG. 10. SPEAR IN FULLY CLOSED POSITION.

orifice. The motion of the tail end of the spear spindle is communicated by a crank to a sleeve 5, which surrounds the rod of the distributing valve, and when the spear has exactly overtaken the blades, this sleeve closes the port which the rod opened, and the spear remains in the new position corresponding to the reduced load. Assuming the load has been entirely removed, the blades move forward to their extreme outward position shown in Fig. 8, and the spear slowly follows until the jet orifice is completely closed. The manner in which the water is dispersed by the blades is shown by Fig. 9. The fixed cover at the top of the nozzle was omitted from the exhibit for the sake of clearness.

The sectional wooden model of the Balanced Valve also, we think, appealed strongly to hydraulic engineers, and showed the action in a very simple manner. Fig. 11 shows the valve in the nearly closed position, and Fig. 12 shows it approaching the fully open position. It will be seen that the pressure of the water on the hollow cylindrical sliding sleeve is balanced on both sides. The only resistances to the motion of the sleeve are the water pressure on the small end surface and the friction of the bearing surfaces, therefore the operation does not require any great force ; at the same time, the maximum area of flow is obtained for a minimum travel. This design of valve has the further important advantages that it is extremely compact and can be dismantled or removed from the pipe line very easily.

In order to prevent any kind of water hammer, the speed of opening or closing is regulated by the Control Screw seen in the upper right-hand corner ; the pressure water in passing into or out of the annular operating cylinder has to follow the spiral passage formed by the square thread, and the frictional resistance thus encountered reduces the velocity of flow of the water to the desired magnitude. The screw and the chamber in which it works are so arranged that on the closing movement more threads have to be followed at the end of the stroke than at the commencement, so that the valve gradually slows down as it reaches its seating ; for opening, the movement accelerates gradually with the stroke. A time control arrangement of this novel type has the great advantage over a simple diaphragm that it is not so liable to become choked, the necessary resistance being provided by a long path of relatively large area rather than a very short path of correspondingly small cross-section.

Steam Turbo-Generator Sets.

The power station in the Palace of Engineering was a complete working representation of a modern municipal power house, and has given the various participants a unique opportunity of showing their plant under working conditions. The total capacity provided was 4,500 KW. in three units, of which two were usually under load, with the third as "stand-by" set. In the boiler house the latest type of coal and ash-handling plants were installed, while the boilers themselves were of the latest water-tube pattern. Two large cooling towers have been built immediately adjacent to the engine room for dealing with the condenser cooling water. At one end of the engine room was a substation containing rotary converter plant for the direct-current supply which supplemented the main three-phase supply throughout the Exhibition.

The arrangements for inspection of the plant by the general public were particularly good ; a gallery some ten feet high ran the whole length of the engine room and was provided with staircases at the ends and centre to permit a continuous stream of visitors. The boiler house was completely open to view at the firing end, and a suitably protected public gangway passed along one side of the substation and through the condenser and boiler house basements.

Of the three generating units, one was a complete product of the "English Electric" Works, while to the other two sets, five different manufacturers contributed various parts.

The "English Electric" Generating unit consisted of a 1,500 KW. 3,000 R.P.M.

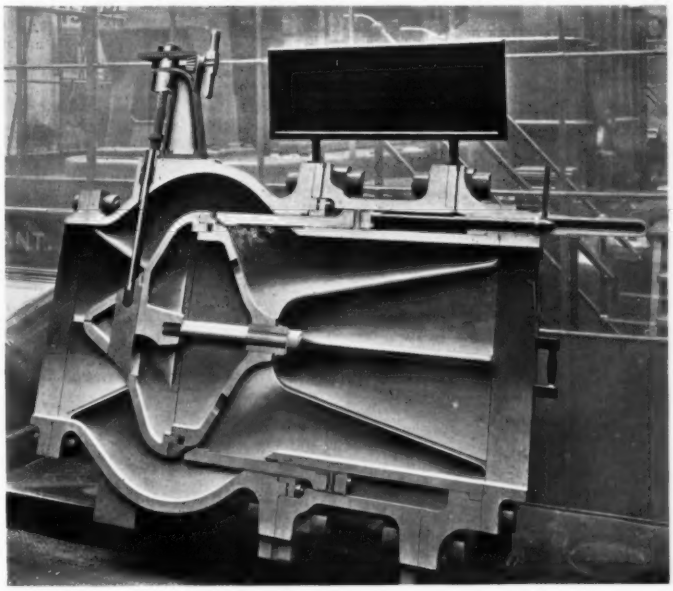


FIG. 11. MODEL OF BALANCED VALVE IN NEARLY CLOSED POSITION.

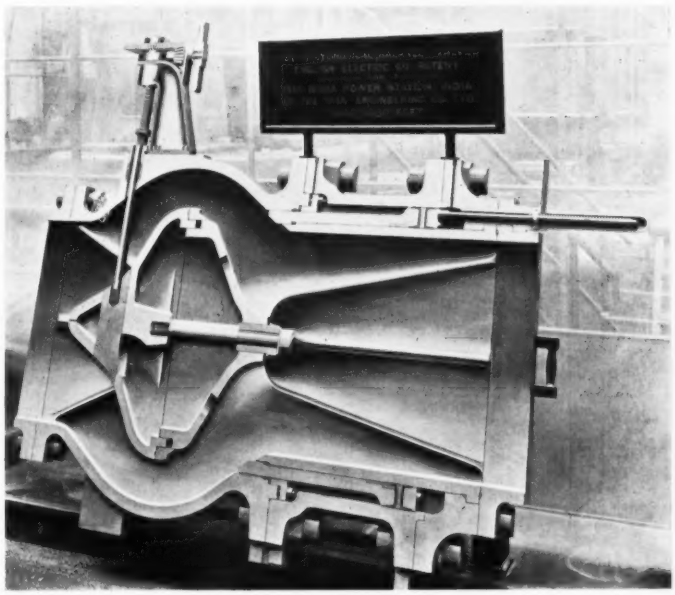


FIG. 12. MODEL OF BALANCED VALVE IN FULLY OPEN POSITION.

Turbo-Alternator of the latest standard design, complete with a 28,000 square feet "English Electric" surface condenser. The turbine is of the impulse type and was supplied with steam at 200 lbs. per square inch, and exhausted into a vacuum of 28½ in. Hg. In spite of its relatively small size, the appearance of this set is striking on account of its high finish, and the simplicity of the layout; a turbine-driven centrifugal oil pump is fitted to the turbine, and a compact gauge pillar was installed in close proximity to the driver's station. Another point of interest must not be omitted, namely, the use of Messrs. Firth's stainless steel for the blading of this machine.

The alternator is a standard machine wound for 3,300 volts, 50 cycles, and was provided with a closed-circuit cooling air system with a Heenan & Froude Cooler.

In addition to this exhibit we showed on our Stand a number of turbine parts consisting of a standard governor, a complete turbine-driven centrifugal auxiliary oil pump, a disc with blading forming one stage of a 15,000 KW. 1,500 R.P.M. unit, and a pair of blades of which the larger is from the low pressure stage of a 16,000 KW. machine and the smaller from the high pressure end of a small turbine for use on the highest steam pressure yet attained.

The details of our standard governor could be closely investigated in the example shown; the features which appealed to engineers were the arrangements for eliminating friction of the moving parts and the ease with which the governor can be dismantled and re-assembled without affecting the adjustment. In the auxiliary oil pump, the rotor is of special interest, in view of its extreme simplicity; on one end of the vertical spindle is the turbine wheel with its blades formed out of the solid disc and at the other end is attached the pump rotor. This little auxiliary is extremely robust and reliable in practice, and receives its steam supply through a diaphragm throttle plate which effectively limits the speed under all conditions.

The various examples of blading showed the high standard of finish produced in machining without the necessity for any hand work.

At the present time, development in the Steam Turbine department is proceeding along several lines, amongst which we may mention the building of 3,000 R.P.M. units for larger outputs and the increasing use of gear driving for both direct and alternating-current generators of fairly small output. We take the opportunity of illustrating a typical geared turbo-alternator set in course of erection. This unit is designed for an output of 750 KW. at 420

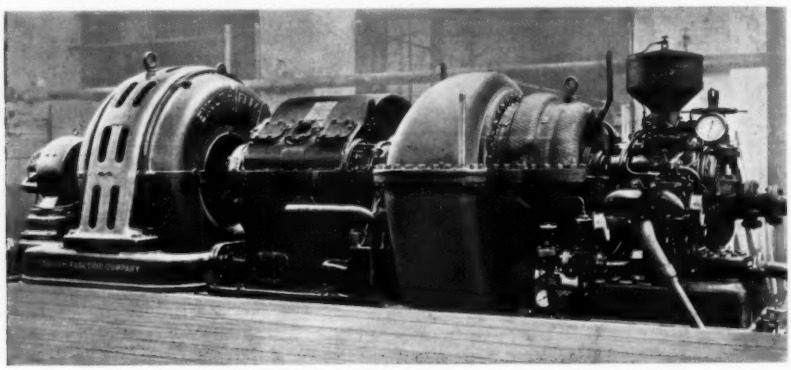


FIG. 13. TEST BED VIEW OF 6,000 R.P.M. STEAM TURBINE DRIVING 750 KW. ALTERNATOR THROUGH GEARING.

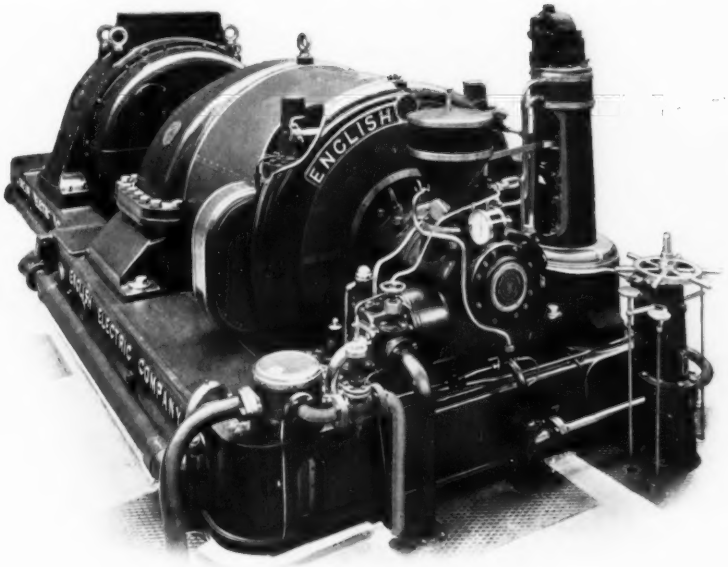


FIG. 14. THE "ENGLISH ELECTRIC" TURBO-ALTERNATOR SET FROM THE TURBINE END.

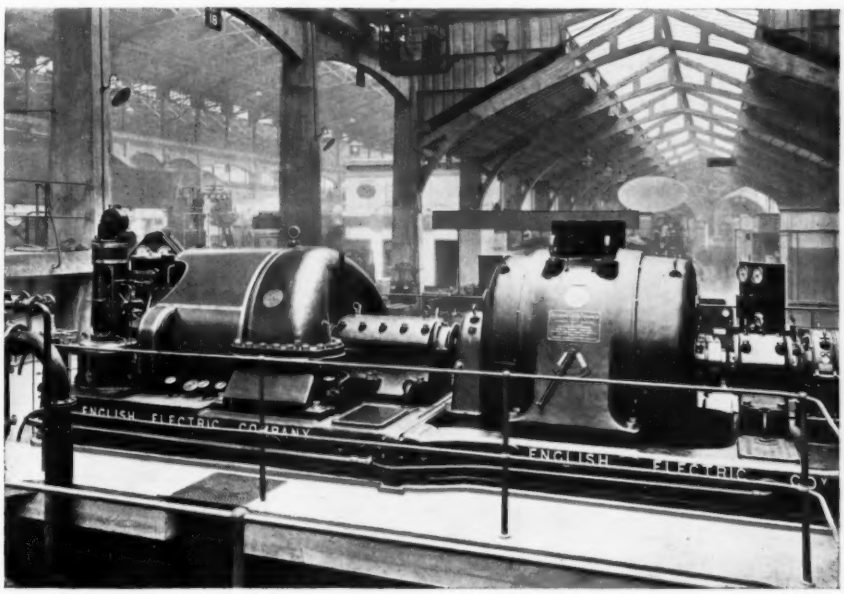


FIG. 15. GENERAL VIEW OF THE "ENGLISH ELECTRIC" UNIT IN THE EXHIBITION POWER STATION.

volts, 50 cycles, and comprises a 6,000 R.P.M. turbine driving one of our standard slow-speed three-phase alternators, Class G.L. at 750 R.P.M. through single-reduction double-helical gearing.

Diesel and Fullagar Oil Engines.

For the development of power on a relatively small scale and in cases where steam plant is prejudiced by the absence of condensing water or facilities for obtaining coal at a reasonable price, the most economical form of prime mover is one which produces power directly from some kind of crude oil. To meet such cases, Diesel engines have been manufactured at our Rugby Works for many years in a range of sizes up to 500 H.P., and the satisfactory results which these have given in all parts of the world indicated the desirability of increasing the range of outputs. After full investigation, therefore, we decided to undertake the manufacture of an extended line of engines working on the Fullagar Opposed-Piston principle with a view to providing units ranging from 750 H.P. to 3,000 H.P.

As an example of our standard Diesel-driven generating plant, we illustrate in Fig. 20, a 500 KW., three-phase plant running in the power house of a provincial supply company.

The design of the Fullagar engine is of considerable interest, and in order to assist the explanation of its principles we made the small

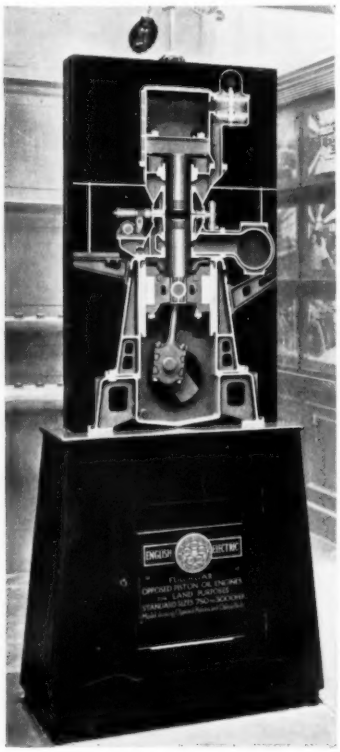


Fig. 16. Fullagar Engine Model, showing Pistons near beginning of stroke.

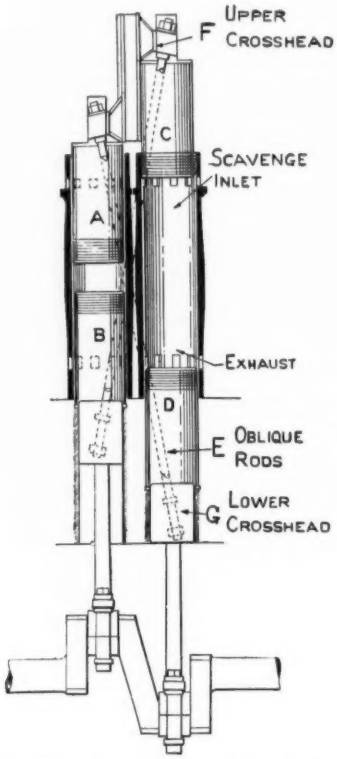


Fig. 17. Diagrammatic Section of a pair of cylinders.

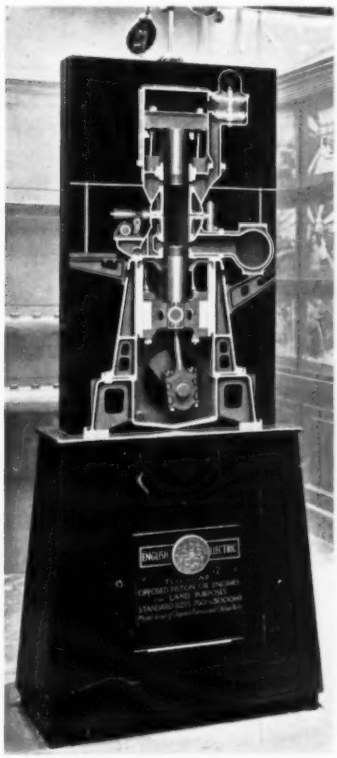


FIG. 18. FULLAGAR ENGINE MODEL SHOWING PISTONS AT END OF STROKE, CYLINDER EXHAUSTING.

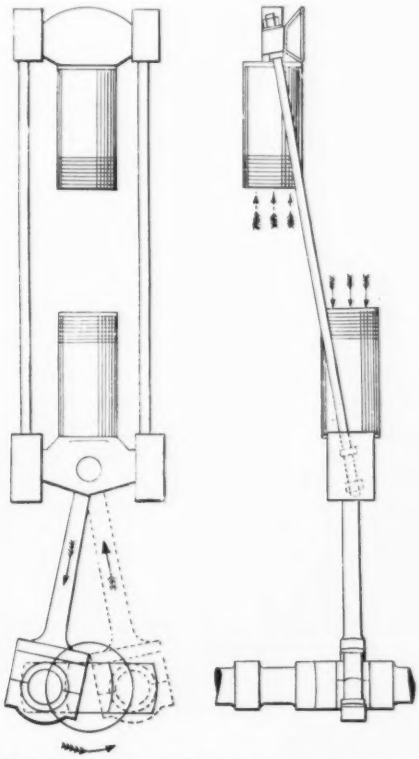


FIG. 19. ARRANGEMENT OF PAIR OF PISTONS AND OBLIQUE COUPLING RODS.

sectional working model exhibited on our Stand (see Figs. 16 and 18). The method of operation will be readily understood by reference to these views and to Figs. 17 and 19. Referring to Fig. 17, combustion takes place between the opposed pistons A and B and forces B to move downward and A upward. Piston A acts on the right-hand crank through the oblique rods E and also draws up piston D in the adjacent cylinder. Piston B acts directly on the left-hand crank and the shaft thus receives two equal and opposite impulses. The side thrust produced by the oblique rods is taken by the cross-heads F and G. It should be noted that the obliquity of the rods is small and less than the maximum obliquity of the connecting rods, so that the lateral forces on the cross-head faces are very small.

The top cross-heads are so designed and enclosed that they act as the pistons or displacers of the scavenge air pumps, an arrangement which avoids complication and reduces the number of parts to a minimum.

It will be seen from Figs. 17 and 18, that the exhaust ports are uncovered slightly before the scavenge inlet ports and when the latter open the scavenge air sweeps right through the cylinder from end to end.

As the pressure in the cylinders acts equally on the upper and lower pistons, the forces upon a pair of cranks are equal and opposite at all times, and the main bearings are relieved of load.

The Fullagar engine has the advantage over any other type of internal combustion engine that it is in effect a double-acting, two-stroke cycle engine without cylinder covers. This design leads automatically to cylinders of small size for a given power in spite of the low mean effective pressure and piston speed which we have adopted. With the construction described, each connecting rod is double-acting, and the effort of each crank is constantly in one direction. A four-crank engine therefore receives four pairs of balanced impulses per revolution, eight in all, and the consequent turning effort is more uniform than that of any other oil engine. Figs. 21 to 23 show views of a complete "English Electric" Fullagar Engine and some component parts. The full load speed varies from 200 to 250 R.P.M. according to the output, and in most cases a suitable direct-current or alternating-current generator of our standard design is direct-coupled to the engine.

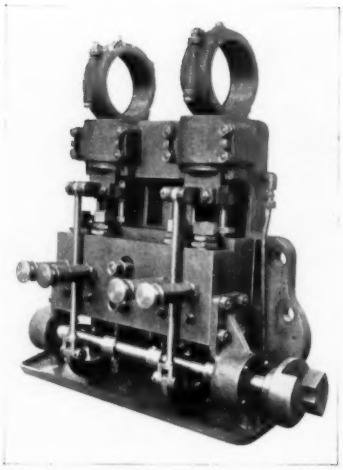


FIG. 21. FULLAGAR ENGINE FUEL PUMPS.

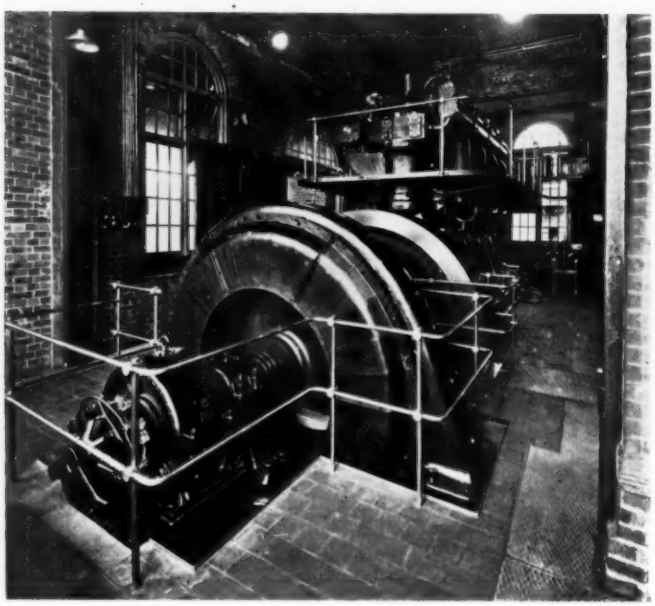


FIG. 20. 500-KW. DIESEL ENGINE AND ALTERNATOR IN THE WORKS OF AN ELECTRICITY SUPPLY CO.

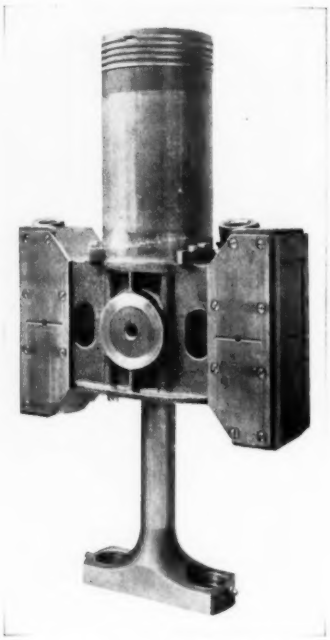


FIG. 22. FULLAGAR ENGINE LOWER PISTON, CROSS-HEAD AND CONNECTING ROD.

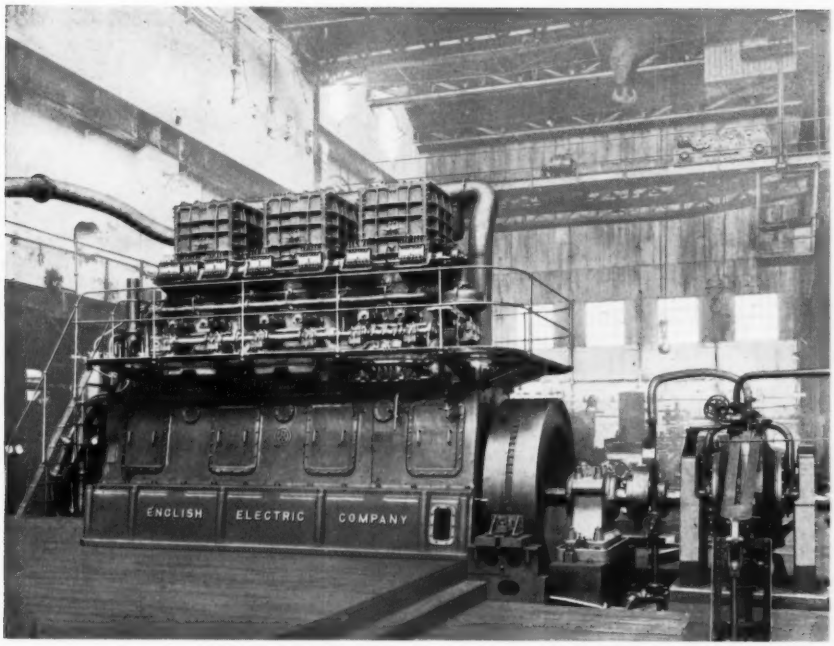


FIG. 23. 1,125 H.P., 6-CYLINDER FULLAGAR ENGINE FOR A MUNICIPAL SUPPLY STATION.

ELECTRIC TRACTION.

Our exhibits in this field were confined to an example of a Camshaft Controller as used on main line locomotives, a large railway motor, three tramcar motors, and one of our latest tramcar controllers of novel design. The design of the electrically-operated camshaft controller has been described fully in these pages, and it will be remembered that the chief feature of this apparatus is that the control operations are effected mechanically by a motor-driven camshaft, thereby ensuring the correct sequence of operation without the necessity of complicated interlocks; the progression is definitely determined and there is no possibility of incorrect operation. The particular unit shown illustrated the control equipment for a locomotive equipped with four 300 H.P. motors on a 1,500 volt D.C. system. The camshaft controller, reverser, contactors, etc., are operated by the master controller seen on the left hand of Fig. 24, and the necessary low-voltage operating current was supplied by a small motor-generator set giving direct current at 100 volts. In order to render clear the progression of the control movements, an illuminated number sign was provided which indicated the particular step arrived at. Referring to the illustration, the camshaft will be seen near the top with the contactors above it and the operating motor and gear box on the left; to the left of the gear box is the position regulator which determines the precise step by step operation of the motor by actuating a relay which alternately energizes and short-circuits the motor armature. In the centre of the second row of apparatus is the group of electrically-operated contactors for field shunting. In the bottom row, from left to right, are the solenoid-operated reverser, motor cut-out

switches, and the two magnetic blow-out line breakers shown with their arc shields lowered so as to expose the contacts. It will be seen that a non-inflammable construction has been adopted throughout, and all operating spindles and finger supports are of steel with mica insulation; the design is both solid as regards adequacy of wearing surfaces, and accurate with a view to interchangeability of parts.

This type of control has been standardised for all kinds of service, and many equipments are in use throughout the world on locomotives and motor coach stock. For the latter case, the apparatus is assembled in a very compact form, either for mounting under the coaches or in the driver's cab, as shown in Figs. 25 and 26 respectively. A master controller for such an equipment is shown in Fig. 27, while Fig. 28 is a near view of an under coach equipment (with covers open) on a seven-coach train on the L.M. & S. Railway.

The D.K. 79 railway motor exhibited was typical of those used for locomotives on the Midi Railway of France, the Japanese Government Railways and other systems, and was of the forced-ventilated type, having a rating of 350 H.P. at 750 volts, and insulated for 1,500 volts. The solid construction of the D.K. motors is too well known to need emphasis, and their durability is well demonstrated by the smaller tramway motor which we exhibited after it had operated on one of the London County Council's cars for a period of over twenty years. This motor is of the D.K. 25A type, and is one of a very large number of machines, aggregating nearly 50,000 H.P. supplied for the L.C.C. system. In Fig. 30, the old motor appears on the left of the group and next to it is mounted its modern equivalent, a D.K. 31C machine. The advance which has been made in design is indicated by the following comparison of some of the most important features. :—

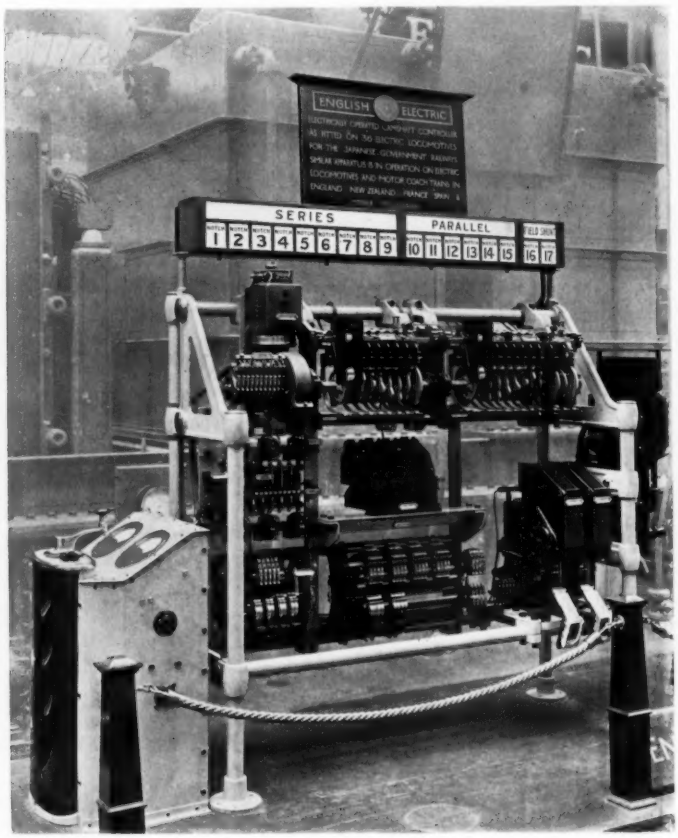


FIG. 24. ELECTRICALLY-OPERATED CAMSHAFT CONTROLLER AND MASTER CONTROLLER FOR MAIN LINE LOCOMOTIVE.

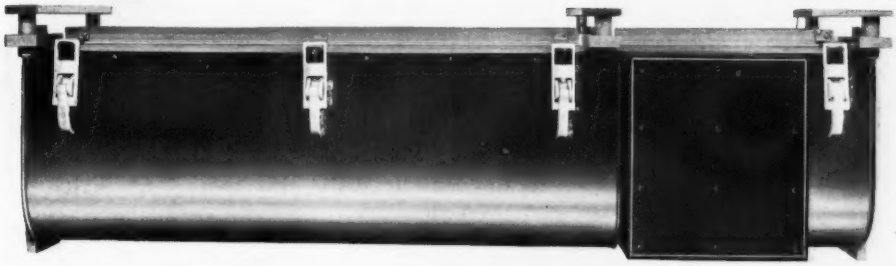


FIG. 25. TYPICAL UNDER-CAR TYPE OF CAMSHAFT CONTROLLER FOR MOTOR-COACH STOCK.

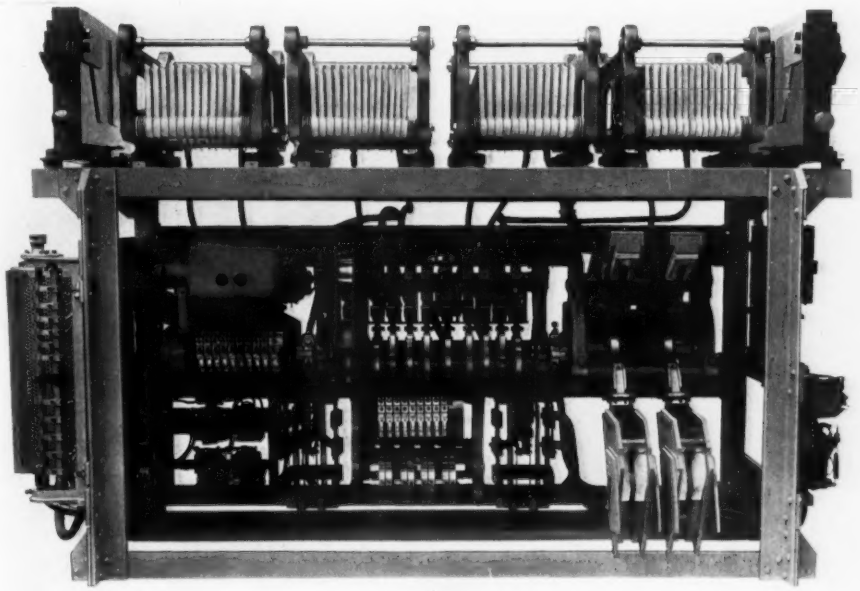


FIG. 26. CAMSHAFT CONTROLLER FOR MOTOR-COACH STOCK; DRIVER'S CAB TYPE.

Motor	D.K. 25A. ...	D.K. 31C.
Bearings ...	Sleeve	Roller.
Casing	Totally enclosed	Ventilated.
Field Magnet...	No Interpoles...	Fitted with Interpoles.
Weight	1,972 lbs.... ...	2,518 lbs.
Rating	25 H.P.	63 H.P.

For an increase of only 28 per cent. in weight the output is $2\frac{1}{2}$ times as great, and the newer machine is the most powerful tramcar motor in use in this country; it is made in both split and box frame types.

It is of interest to note that, so far as our records go, they show that a total of well over 900,000 H.P. of D.K. traction motors have been turned out from Preston Works.

The D.K. tramcar controller fitted with the D.K. metallic-shield blow-out is in operation in every part of the world; the latest development of this apparatus takes the form of the CDB type controller which was shown on our stand and is illustrated in Fig. 29. This is one of a number in hand for the L.C.C. system, and embodies camshaft construction adapted to hand operation.

Where traffic conditions are severe and high power motors are used, it is considered that the ordinary drum-type controller is no longer suitable, and it is for this reason that the camshaft type controller has been introduced. The construction is on the mica-steel principle throughout, and this results in a piece of apparatus which is practically indestructible. With the camshaft type of contact used, a definite rolling and wiping action takes place between the two opposed contacts, and a definite contact pressure is ensured without increasing the turning effort at the driver's handle. Owing to the rapidity with which the contactors open, and the provision of a blow-out system of our standard metallic-shield type, there is very little burning, and this in conjunction with the absence of moving segments reduces the renewals to a very low figure indeed.

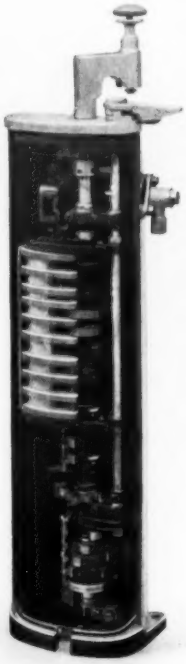


FIG. 27. MASTER CONTROLLER FOR CAMSHAFT CONTROLLER ON MOTOR COACH STOCK.

FIG. 28. UNDER-CAR TYPE OF CAMSHAFT CONTROLLER ON L.M. & S.R. MOTOR COACH TRAIN.

Another example of a standard tramcar motor is shown in the D.K. 30 machine of 40 H.P. rating; this is a size used very extensively on any track gauge from 1 metre upwards,

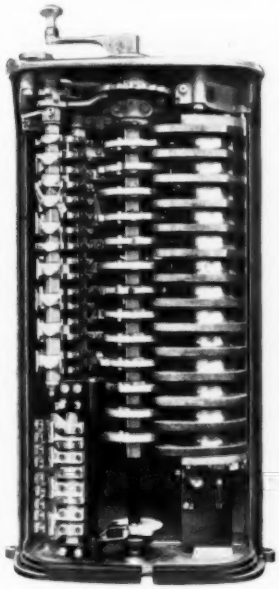


FIG. 29. HEAVY DUTY TRAMCAR CONTROLLER WITH CAMSHAFT CONSTRUCTION.

and is made in the box or split frame designs. In accordance with our standard practice a system of positive ventilation is embodied in the machine, so that maximum output with minimum weight is obtained.

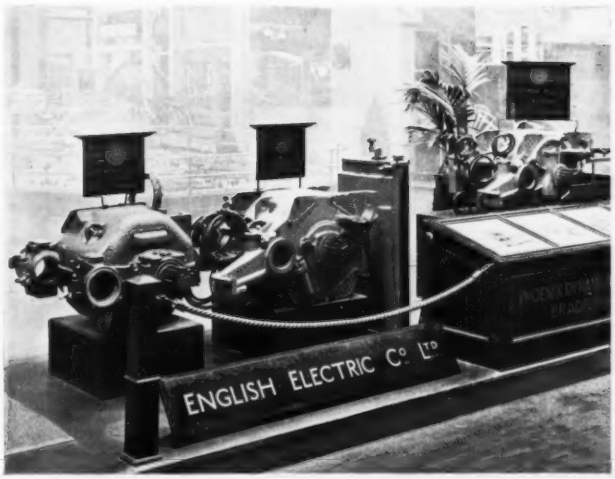


FIG. 30. GROUP OF D.K. TRAMCAR MOTORS.

Before closing this section, we should like to refer to a particularly fine model shown on the stand of the North British Locomotive Company (see Fig. 31), which reproduces one of the 100-ton express locomotives which we recently supplied to the Japanese Government Railways, the mechanical portions having been manufactured by the firm referred to; these machines were described fully in our number for April last.

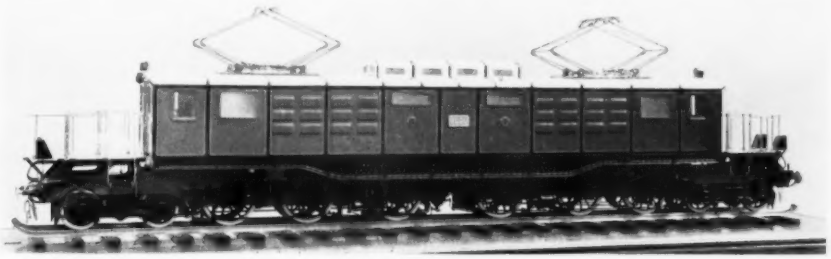


FIG. 31. SCALE MODEL OF "ENGLISH ELECTRIC" 100-TON EXPRESS LOCOMOTIVE EXHIBITED BY THE NORTH BRITISH LOCOMOTIVE COMPANY.

Transformers.

The 1,100 KVA. 6,600/370 volt, 3/6-phase Transformer shown in Fig. 32 is an example of the entirely re-designed line which we have recently developed, and although it is usually difficult to find points of interest or novelty in the outside of a transformer tank, the reader will notice that in this case semi-circular ends have been adopted, with the tubes arranged radially, instead of the customary square corners. Not only does this result in a more pleasing appearance without appreciable difference in cost, but there is also a definite improvement in the oil circulation, combined with a saving of floor space; at the same time this design gives a higher factor of safety in regard to both mechanical strength and oil tightness. The unit shown is for use with the 1,000 KW. Rotary Converter mounted close by (see Fig. 34), and is provided with the necessary secondary tappings for tap starting. In the substation adjoining the power house there was in operation in connection with the "English Electric" Rotary Converter, a 550 KVA., 3,300/325 volt, 3/6-phase Transformer, also provided with the necessary starting tappings; this plant is shown in Fig. 33. Both of these transformers are designed for standard temperature rise and overloads, and are typical of the units supplied in large numbers, not only for feeding rotaries, but for use in a great variety of situations for linking up systems or plants of different working pressures.

Fig. 32. 1,100-KVA. 3-phase Transformer in Tubular Tank with half-round ends.

Standard lines of transformers have now been put on the market to meet all the requirements of transmission and distribution service. Close to the 1,100 KVA. unit was mounted a 5 KVA. pole type transformer for low-voltage distribution direct from an overhead line, and in contrast to this we take the opportunity of referring to an order which we have recently received for twelve single-phase units, which will rank amongst the largest yet manufactured in this country. These transformers, which are destined for a large hydro-electric scheme in India, are of the oil-immersed water-cooled type, and will operate in banks of three, the particulars of each three-phase bank being as follows:—Output, 27,000 KVA; normal ratio 100,000/23,100 volts; Connections, Delta-Star for working on a 50-cycle, 13,350 volt supply. Intermediate between these examples are units of all sizes, designed

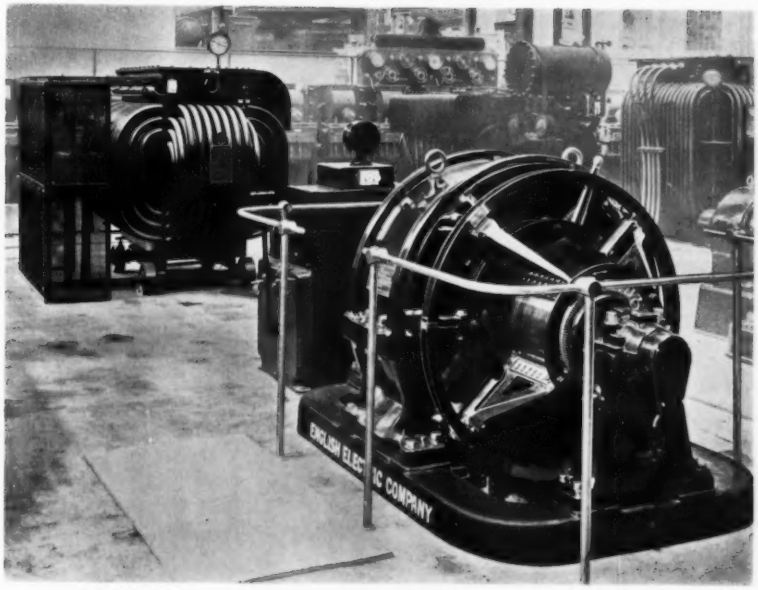


FIG. 33. 500 KW. ROTARY CONVERTER WITH TRANSFORMER AND TAP STARTING PILLAR IN THE POWER HOUSE SUBSTATION.

for the most economical working upon the various classes of load which occur in practice, and in particular much attention has been given to the standardization of transformers with the lowest practicable iron losses, with a view to giving high economy on lighting or similar loads where the load factor is somewhat poor. As a general rule, a core type of construction is used, and, according to the size and conditions of service, the transformer may be of the ordinary oil-immersed type or arranged for cooling by circulation of water or oil, or in certain cases the air-blast type is adopted. Special attention is given to a suitable grading of the insulation of the high-tension coils and to the provision of adequate ducts for the circulation of the oil between all parts of the windings.

In addition to a complete range of transformers for ordinary indoor use, standard units can be supplied for outdoor installation or for use in confined spaces as occur in mining work.

Visitors who wished to study constructional details were much interested in the examples of coils, insulators and other parts which were shown separately.

ROTARY CONVERTERS.

Two examples of these machines were to be seen, and this may be taken as an indication of the importance and continual expansion of this branch of the Company's business. The demand for Rotary Converters continues to increase proportionately with the development of electrical supply throughout the world, and this class of machine will always remain an essential item in every system where distribution is made by alternating current, but the energy has to be utilised as direct current either for railways, electro-chemical or general power and lighting purposes.

The design of "English Electric" rotary converters is thoroughly modern, and whether they are reviewed from the mechanical or

electrical standpoint, these machines will be found to embody the most recent improvements. It is gratifying to record that we have received many acknowledgments from users testifying to the satisfaction which our rotaries have given in operation. In the substation adjoining the Power House was installed a 4-pole unit (see Fig. 33) running at 1,500 R.P.M. and giving 500 KW. at 440 volts; the converter was arranged for starting by tappings, and a suitable transformer and starting pillar were provided. This set fed into the direct-current, 3-wire system for the supply of various plant throughout the Exhibition, and took its supply from the 3,300 volt, 3-phase, 50-cycle busbars of the Power Station. On the stand itself was installed a similar machine, having a capacity of 1,000 KW., with its transformer and tap starting pillar. This plant is shown in Fig. 34.

A novel feature present in both machines is the roller type of bearings used in place of the older sleeve bearings; in adopting roller bearings, not only for small industrial motors, but also for large machines of many types, we have been pioneers, and the entire success of this departure has been abundantly proved.

Another feature which these exhibits illustrate very clearly is the saving of floor space effected by using the "tap" starting method instead of a pony motor, although the latter can be fitted when a definite preference is shown for it; we invariably leave our clients a free choice of starting method, but our records show that 97 per cent. of the machines produced have been for starting by tappings. We are now manufacturing machines of 2,000 KW. output (see Fig. 35) arranged for tap-starting, and this probably represents the biggest output in this country where modern tap-starting has been

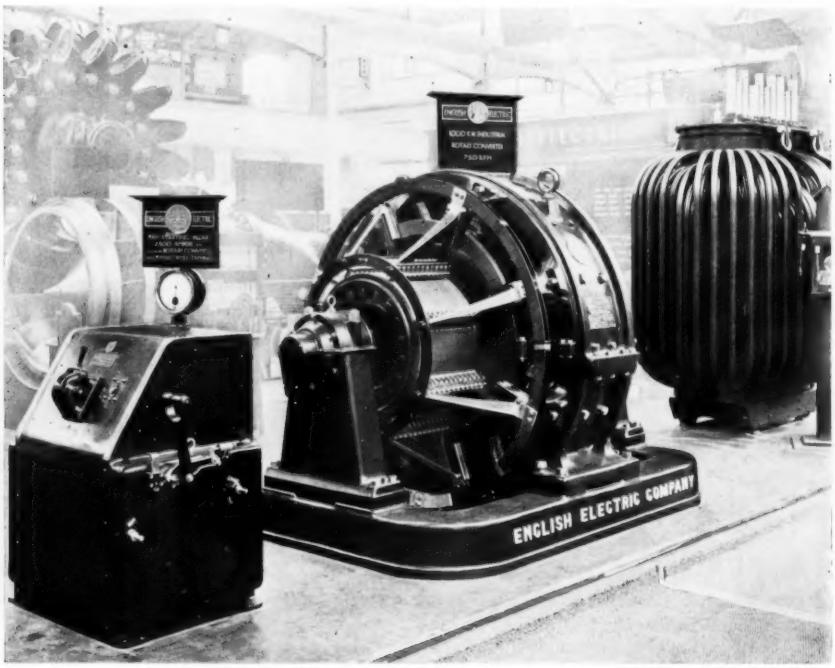


FIG. 34. 1,000 KW. ROTARY CONVERTER WITH ITS TRANSFORMER AND TAP STARTING PILLAR.

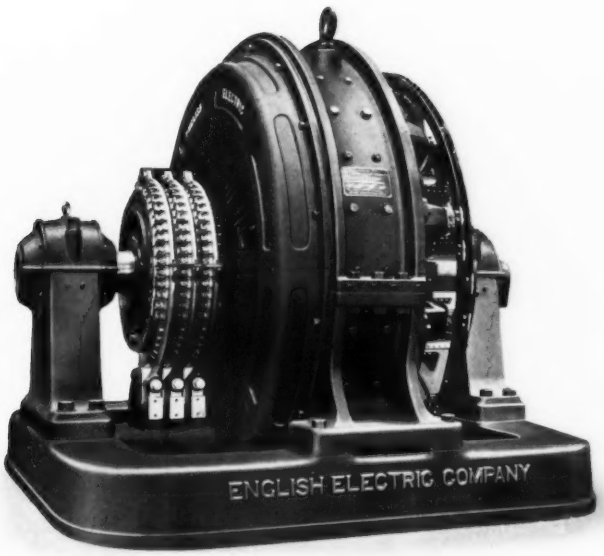


FIG. 35. 2,000 KW. "ENGLISH ELECTRIC" ROTARY CONVERTER ARRANGED FOR TAP STARTING.

applied; at the same time we are prepared to produce similar machines up to any size, provided of course, that the conditions of the power supply permit. Good ventilation and ease of installation are both facilitated by the adoption of relatively high bearing centres.

It has been generally remarked that the finish of our converters is exceptionally good, and is indeed what is usually termed "Exhibition" finish, and as a matter of fact the machines exhibited were not specially prepared and are simply finished in our standard manner.

Every detail of the design has been worked out most carefully with the object of securing the highest reliability under working conditions. The commutator construction is of the non-arch-bound type, which ensures freedom from distortion, and the brush gear, both D.C. and A.C., is of a thoroughly serviceable and appropriate design.

A complete line of these machines has been designed for the usual voltages and periodicities which occur in industrial and municipal service as well as a range of units suitable to meet the special conditions met with on electric traction systems. In all cases a very high standard of commutation is attained, and the machines are capable of heavy overloads; they have a high efficiency and comply with accepted practice in the matter of temperature rise.

The compact form of ironclad starting pillar is provided with three positions for "off," "start," and "run" respectively, and is equipped with centre-zero voltmeter and field reversing switch. Starting by tappings with this form of control is easy, simple and satisfactory when the rotary has been properly designed for this method of starting; the plant is self-synchronising and no adjustments are necessary to the speed or voltage. Starting can

be effected by a relatively unskilled attendant in from 15 to 60 seconds, according to size.

The transformers for use with these rotary converters follow generally the standard designs of our apparatus of that class, to which reference is made in the previous section.

Industrial Applications of Electricity.

So far we have dealt with a number of specialities which are associated with electrical generation and distribution on a large scale, but on the electrical side of our manufactures there are still a very large number of standard machines required for the application of electricity to industrial purposes. These comprise motors of all kinds and sizes, generators for small isolated plants, and the multitudinous items of switchgear for controlling these items. All these form an important section of our business. In point of size and power, a very wide range indeed is covered by modern industrial electric motors, extending in the case of our standard machines, from a unit giving ¼-H.P. and weighing about 50 lbs. to a 300-ton rolling mill motor of 19,000 H.P. The larger machines were represented on our stand in photographic form only, and many interesting views were shown of all sizes and types of winding engine and rolling mill drives; plants of these kinds are frequently described in detail in the pages of this Journal. For ordinary applications of electric power, the motors employed are of more modest dimensions, the individual output seldom exceeding a few hundred horse power, and a comprehensive selection of such machines was to be found either on our stand or scattered throughout the Exhibition.

In order to render easier the references to various motors and motor drives, we should like to make it clear that for ordinary industrial purposes our standard lines of motors are sub-divided as shown in the following table :—

	Small and Medium Outputs.	Medium and Large Outputs.
Direct Current.	A.C.B. Motors.	C.S. Motors.
Alternating Current.	A.G. Induction Motors (Squirrel Cage). A.G.S. Induction Motors (Slipring). and for smaller outputs K. & K. S. Motors.	L.S. Induction Motors. L.A.S. Asynchronous-Synchronous Motors. G.L. Synchronous Motors.

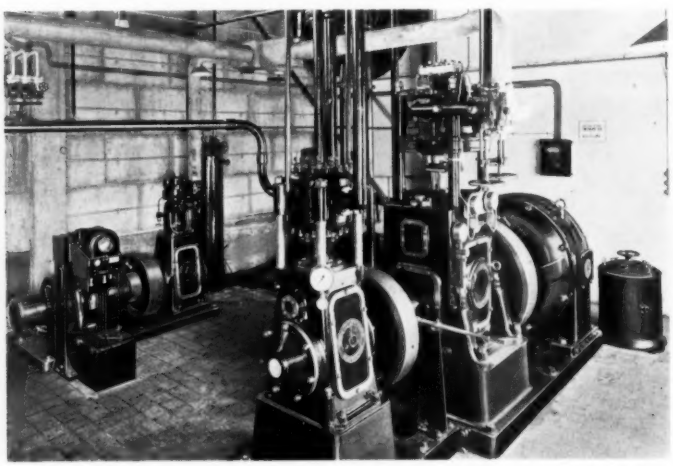


Fig. 36. Ammonia Compressors at the Ice-making & Refrigerating Plant.

For still smaller outputs there are in addition the loom-type induction motors, class P.W.R. As the main power supply in the Exhibition was alternating current, there were very few direct-current motors installed, and our descriptions will therefore refer mainly to A.C. motor drives.

One of the most interesting examples was to be found near the south-west entrance where an unpretentious building housed a plant of no little importance.

It was the refrigerating plant installed by Messrs. Peter Brotherhood, Ltd., for serving Messrs. Lyons many places of refreshment. In addition to making 20 tons of block ice every day, the plant maintained the necessary cold storage temperatures in an ice store of about 100 tons capacity, a frozen meat store of 5,000 cubic feet, a chilled meat store of 7,000 cubic feet, and an ice cream room holding 2,000 gallons of that commodity. Each room was kept at a different temperature suited to its contents. The freezing plant included two Ammonia Compressors driven by "English Electric" motors of 85 H.P. and 15 H.P. respectively, the latter acting as a standby for use when only the cold stores had to be dealt with. The larger set is seen in Figs. 36 and 37, while the smaller one is visible in the background of the first-named picture. The 85 H.P., 264 R.P.M. motor was of our standard L.S. three-phase Induction type, provided with special chemical-proof insulation, and ran practically night and day throughout the summer months. It was started by one of our "pot" type Liquid Starters, size LG. 100, and provided with an ironclad main control switch Class S.X.B. The small unit was driven by an A.G.S. motor, and controlled by an oil-immersed rotor starter unit seen on the left of Fig. 36. In connection with this type of plant, we may refer also to two exhibits on the stand of Messrs. J. & E. Hall, Ltd., in the Palace of Engineering. Fig. 39 shows an ammonia compressor direct-coupled to an L.S. Induction motor of 95 H.P., while

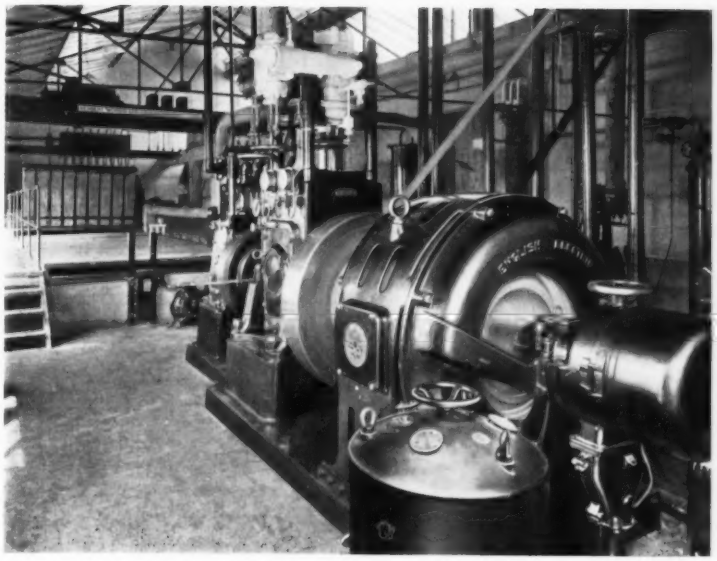


FIG. 37. GENERAL VIEW OF ICE-MAKING PLANT IN OPERATION.

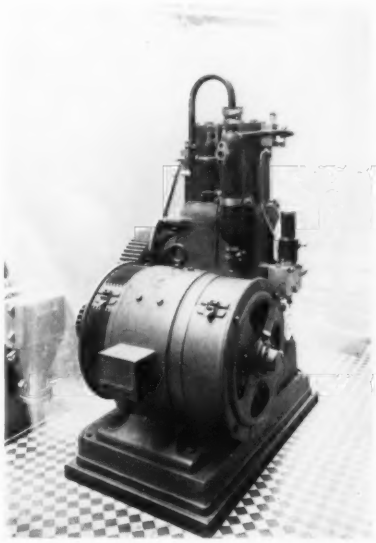


FIG. 38. "HALL" CO_2 COMPRESSOR AND "ENGLISH ELECTRIC" D.C. MOTOR.

Fig. 38 is a smaller CO_2 compressor driven by a direct-current motor of our standard C.B. class.

Induction motors of the L.S. range have been standardized up to the very largest outputs required, and as an example of the sizes which were too large to find a place in the Exhibition, we show in Figs. 40 and 41, the rotor and stator of a 2,500 H.P. motor recently completed. This machine has a full load speed of 250 R.P.M. on a 2,200 volt, 50-cycle circuit, and will be provided with an "English Electric" Phase Advancer.

In view of the great attention now given to power factor improvement, particularly in connection with slow-speed motors, driving fans, compressors or similar machines which run for long periods, the Asynchronous-Synchronous Motor shown on our Stand and illustrated in Fig. 42, is of considerable interest. These Class L.A.S. Motors are similar in general appearance to the L.S. Induction Motors above referred to, but are provided with a small direct-coupled exciter, and so arranged that, although they operate as induction motors at starting or on heavy overloads, they run normally as synchronous machines, and as such can be adjusted to have a power factor which is unity or even leading. The machine shown has a rating of 170 H.P. at 187 R.P.M. when running on a three-phase, 50-cycle, 415 volt supply, and is a duplicate of five machines recently supplied for the direct driving of compressors, a kind of service for which these machines are specially suitable.

An alternative method of power factor improvement is the use of an "English Electric" Oscillating Phase Advancer, a piece of apparatus which is connected in the rotor circuits of an Induction motor, and supplies the necessary magnetizing current instead of this being drawn from the mains. An example of this novel type of machine was installed in the compressor room of the Model Coal Mine, where an air compressor

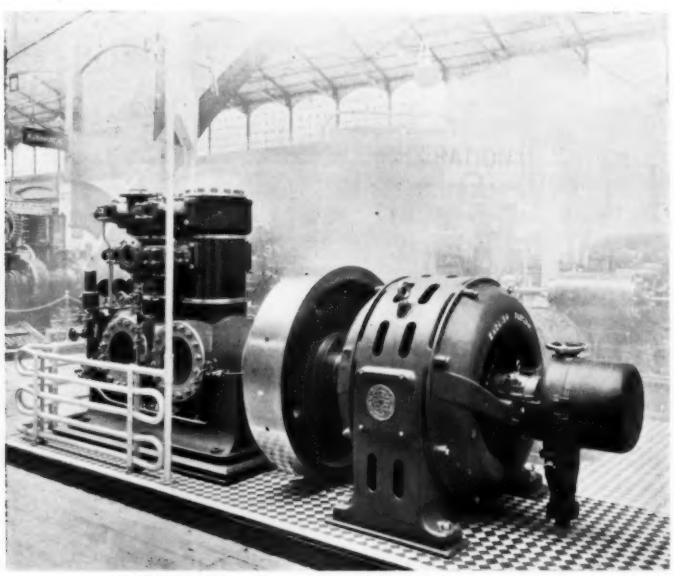
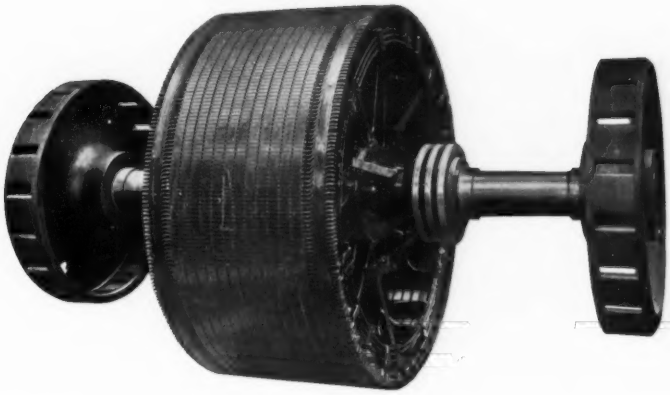
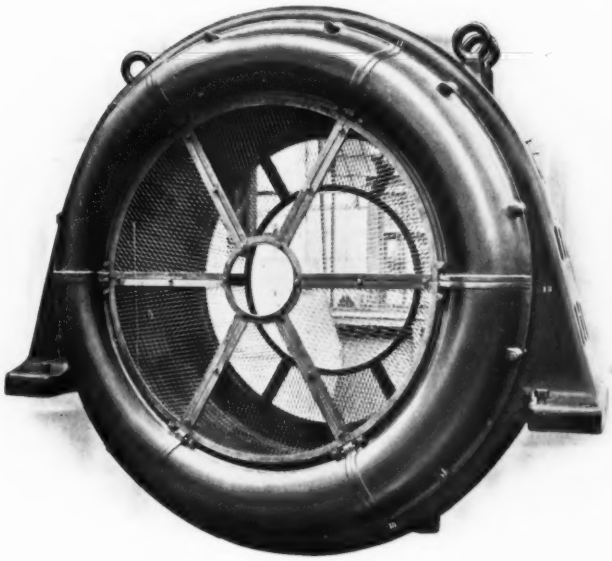


Fig. 39. Ammonia Compressor on the stand of Messrs. J. & E. Hall, driven by 95 H.P. "English Electric" Induction Motor.





FIGS. 40 AND 41. THE ROTOR AND STATOR OF A 2,500 H.P. CLASS L.S. 3-PHASE INDUCTION MOTOR RECENTLY SUPPLIED TO AN INDUSTRIAL UNDERTAKING.

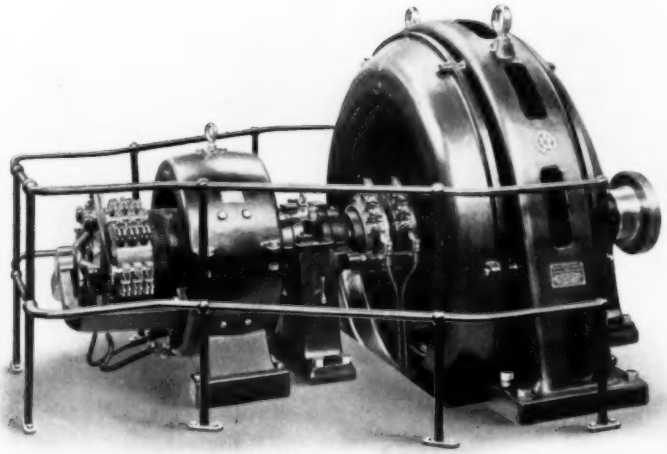


FIG. 42. 170 H.P. 3-PHASE ASYNCHRONOUS-SYNCHRONOUS MOTOR FOR DRIVING COMPRESSOR.

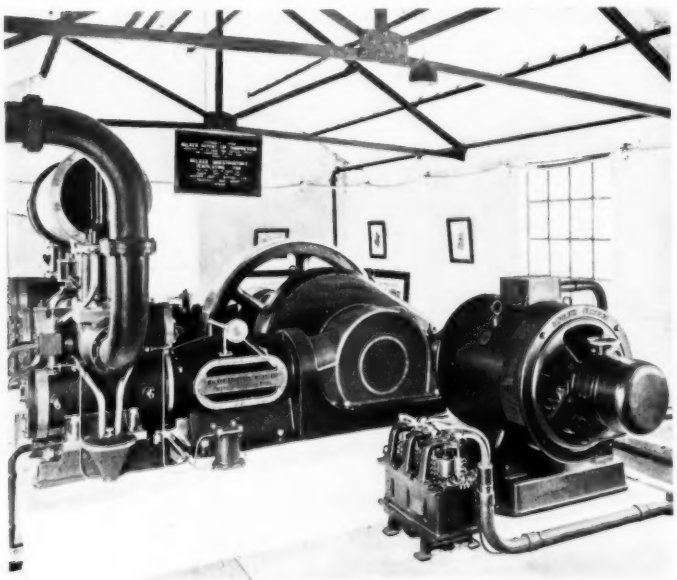


FIG. 43. AIR COMPRESSOR IN MODEL COLLIERY, DRIVEN BY 186 H.P. INDUCTION MOTOR, WITH OSCILLATING PHASE ADVANCER.

by Messrs. Walker Bros. operated for the supply of coal cutting and other machines. The drive was by one of our standard A.G.S. Induction motors of 186 H.P., shown in Fig. 43, in the foreground of which is seen the associated V. 10 Oscillating Phase Advancer. Fig. 44 shows the liquid starter, control switchgear and the small motor-generator set for supplying the requisite direct current for exciting the Phase Advancer. A description of the phase advancer appeared in our number for October, 1921.

Some good examples of fairly heavy drives by our standard A.G.S.

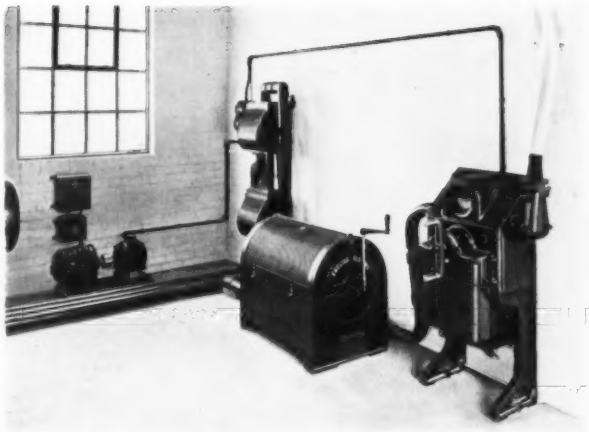


FIG. 44. CONTROL GEAR FOR INDUCTION MOTOR WITH OSCILLATING PHASE ADVANCER.

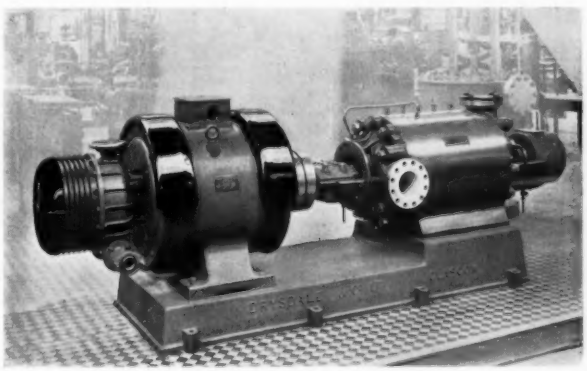


FIG. 45. CANOPY PROTECTED INDUCTION MOTOR DRIVING "DRYSDALE" TURBINE PUMP.

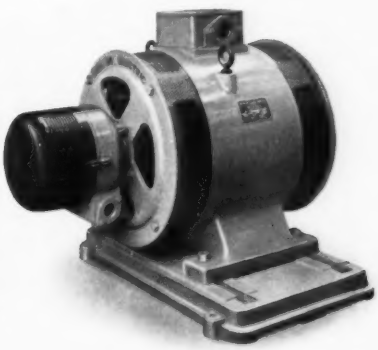


FIG. 46. INDUCTION MOTOR FOR DRIVING SWITCHBACKS.

industrial motors were to be seen in the haulage plants operating the three large switchbacks. The type of motor used is shown in Fig. 46, while Fig. 47 is a panoramic view of one of the switchbacks in the Amusements Park. A drive of this nature is somewhat severe, as the full load is thrown on and off quite suddenly as the full ascending cars are coupled to and released from the ropes.

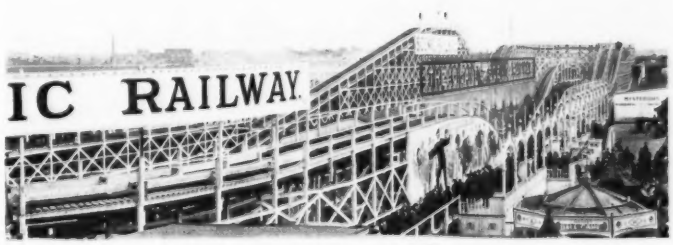


FIG. 47. THE SCENIC RAILWAY, DRIVEN BY "ENGLISH ELECTRIC" INDUCTION MOTOR.

Space was found on the stand for a comprehensive group of direct-current and alternating-current motors, including loom motors, a vertical spindle machine and representatives of the standard enclosed-ventilated, totally-enclosed and flame-proof types, a general view of which is shown in Fig. 48. Another interesting type for use where protection is needed against dripping water, etc., is the canopy protected machine, Fig. 45, shown on the stand of Messrs. Drysdale & Co., in conjunction with one of their high-lift turbine pumps. Finally, we show in Fig. 49 a general view of the Pumping House situated at the side of the large main reservoir, in which were installed three Worthington-Simpson centrifugal pumps direct-coupled to motors of our A.G.S. Class. These sets had an aggregate capacity of 120,000 gallons of water per hour, and were controlled by the "English Electric" Ironclad Unit type switchboard seen on the gallery at the distant end.

A number of other small motors were in operation in the Textile section of the Palace of Industries, and in several of the Colonial Pavilions.

Direct-current generators suitable for small central stations or works plants were installed on several stands in connection with slow-speed prime movers, and Fig. 50 shows a typical unit of this kind, driven by a steam engine, which formed part of the direct-current generating plant for the Exhibition. The steam plant by Messrs. Richard Garrett & Co., was one of their semi-stationary condensing engines with self-contained boiler and drove an "English Electric" "C" class generator, giving 200 KW. at 170 R.P.M. Messrs. Blackstone showed a twin-cylinder horizontal crude-oil engine direct-coupled to a similar generator of 220 KW. output. A vertical gas engine of the National Gas Engine Co.'s three-cylinder standard type, was similarly coupled to a "C" class generator of 110 KW.

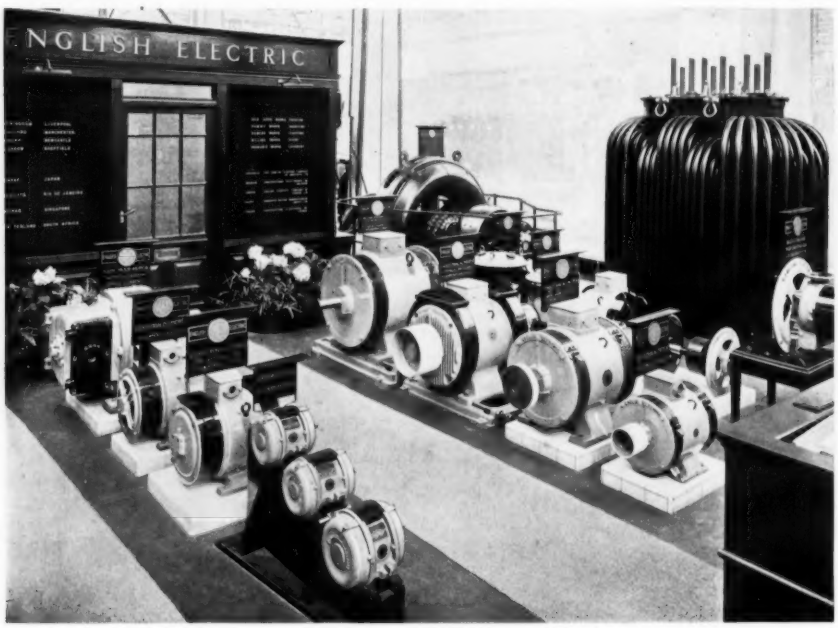


FIG. 48. GROUP OF STANDARD INDUSTRIAL MOTORS FOR DIRECT OR ALTERNATING CURRENT.

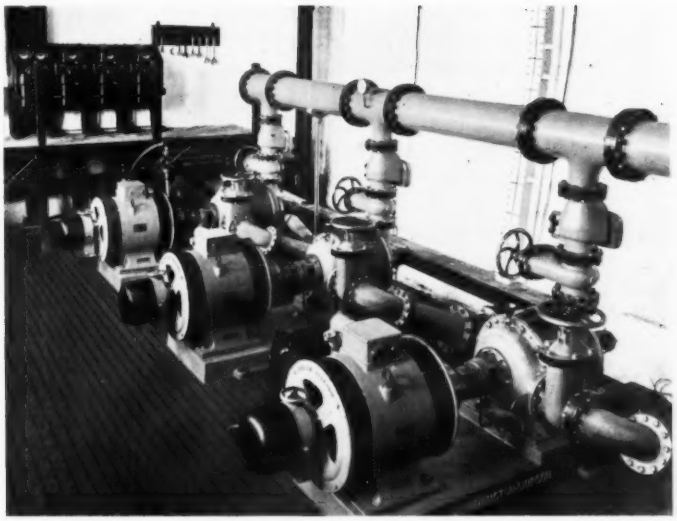


FIG. 49. THE PUMPING HOUSE IN THE EXHIBITION GROUNDS.

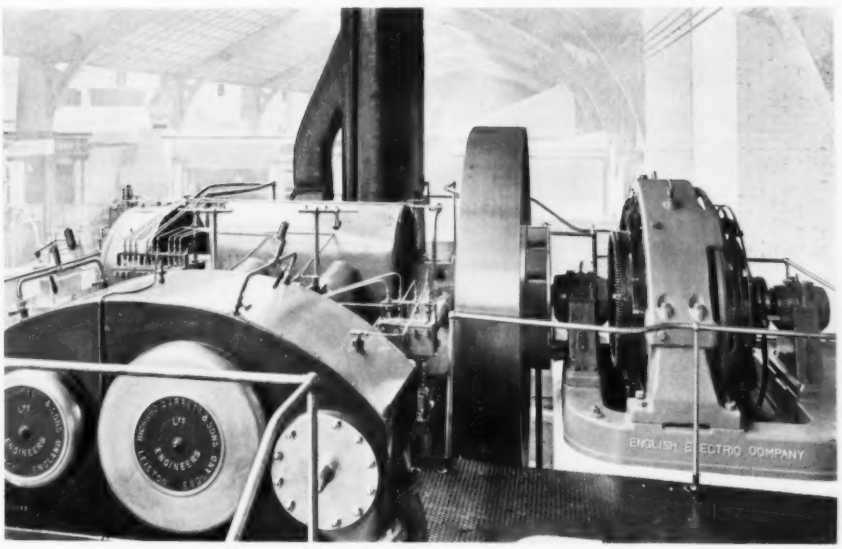


FIG. 50. "GARRETT" SELF-CONTAINED STEAM PLANT DRIVING D.C. "ENGLISH ELECTRIC" GENERATOR.

SWITCHGEAR.

As the most important pieces of switchgear are necessarily of a bulky character, it was not possible to show more than a few examples, but nevertheless this accessory apparatus, which is so vital to all electrical plants, continues to fill a large and growing section of our Stafford Works. Referring to Fig. 51, in the foreground is an ironclad truck unit of our standard type, which is designed for the control of alternating-current circuits, and has a rupturing capacity of 120,000 KW. on 11,000 volts. In this country the evolution of control apparatus for A.C. circuits has tended more and more towards standardized ironclad units of uniform size, which can be assembled together to form a complete switchboard of the desired scope, and the truck unit finds increasing favour as one of the latest developments in this direction for substation work. While it has the advantages common to other unit constructions, that it is simple in first erection and subsequent extension, the truck design is particularly distinguished by the complete accessibility which it affords for the inspection or adjustment of all parts. Each unit consists of a fixed cell and a wheeled carriage or truck, and when the truck is withdrawn it may be wheeled away to a convenient position for examination or adjustment, and the interior of the cell can be thoroughly inspected. Suitable mechanical interlocks ensure that a truck can only be withdrawn when the main circuit-breaker is in the open position and the act of withdrawal causes shutters automatically to close the openings in the cell through which the truck contacts pass. The unit shown is provided with a main triple-pole oil-immersed circuit-breaker having low voltage and overload releases with time limit fuses, watthourmeter, ammeter, voltmeter and the necessary current and potential transformers. Not only does this design meet fully the essential requirements of safety and sound mechanical and electrical construction, but it is also very compact, robust and of good appearance.

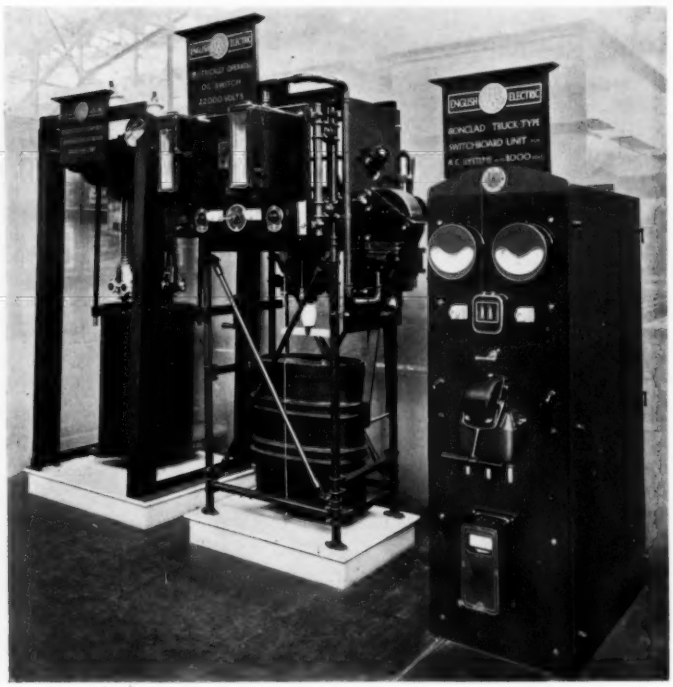


FIG. 51. EXTRA-HIGH-TENSION TRUCK UNIT AND HEAVY-DUTY OIL-IMMERSED CIRCUIT-BREAKERS.

To the left of the truck unit is an electrically-operated oil-immersed circuit breaker of our OKB. class, suitable for pressures up to 22,000 volts. This line of oil breakers has been designed for power station use where a considerable rupturing capacity is necessary, and is particularly adapted for remote electrical operation; it will be seen that the oil tanks are of very substantial

construction and they are, in fact, tested to a pressure of 250 lbs. per square inch. Special means are adopted to ensure efficient ventilation and circulation in the air space above the oil, in order to prevent an accumulation of explosive gases.

In most cases, the circuit-breakers are required for three-phase circuits, and three units are then mounted side by side, in which case the normal position of the solenoid operating mechanism is on the front of the panel behind which the breakers are situated; in the Exhibition example it was mounted at the side for greater convenience.

For actuating the circuit-breaker a special form of master switch with removable key is used, and these are, of course, normally mounted on a control desk in a switch room quite separate or remote from the switch house itself; in the illustration the master switch is in the centre at the bottom of the slate panel, and on either side of it are the red and green indicating lamps. The breaker was arranged for operation from a direct-current 100-volt supply, and all the movements could be observed and the various interlocks, trips, etc., tested.

Next in order we have an example of a still larger type of oil-immersed circuit-breaker of great rupturing capacity, and for use up to 33,000 volts, a type which has stood the test of considerable service on large railway and other power schemes in many countries. Here again, the question of space restricted us to showing a single-pole unit only instead of a complete triple-pole breaker, but the important features could be observed quite fully. A very high rupturing capacity has been attained in this design by the use of a high speed of breaking circuit and by subdividing the arc at four breaks which are arranged in a special form conducive to a maximum magnetic blow-out effect. The usual method of operation is by means of a powerful solenoid which transmits its power through a system of levers and steel rope.

FIG. 52. ARRANGEMENT OF HEAVY-DUTY OIL-IMMERSED CIRCUIT-BREAKERS IN THE SWITCH HOUSE OF A LARGE MODERN POWER STATION.

Fig. 52 shows cubicles in the switch house of a modern municipal power station, in which each three-phase unit is entirely isolated, and the operating mechanism, busbars, etc., are mounted on an upper floor of the building.

In addition to the large switches referred to above, we have a complete range of oil circuit-breakers down to the quite small unit, Class SXD, shown in Fig. 54, which was the main distribution unit on our stand for controlling two three-phase power circuits. The main oil breaker is mounted on the right-hand side, and above and below the busbar chamber are triple-pole air-break switches and fuses for the circuits.

Turning now to the motor control apparatus shown in Fig. 56, we have, reading from left to right, an oil-immersed auto-transformer starter, suitable for squirrel-cage induction motors up to 50 H.P., in the centre a rotor

Fig. 53. 1,500-volt D.C. Air-Break Circuit-Breaker with Metallic-Shield Blow-out.

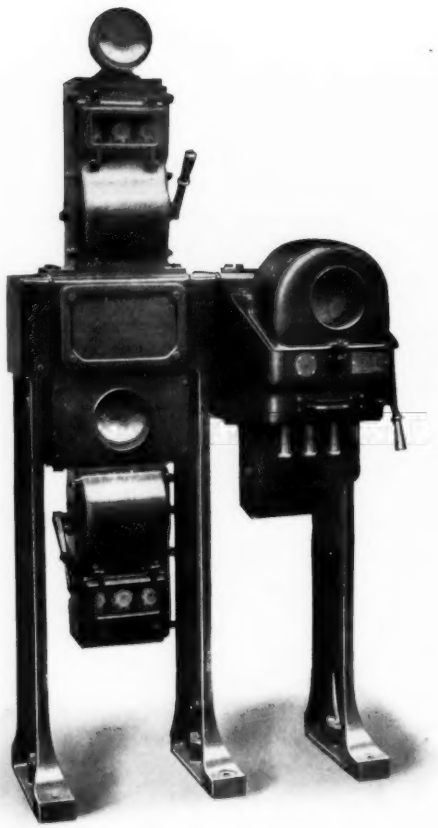


Fig. 54. Small Ironclad Distribution Unit with Main Oil Circuit-Breaker.

starter with oil-immersed circuit-breaker and oil-immersed rotor resistance for slipring motors of medium size, and on the right one of our well-known SXA ironclad draw-out units. Of the latter, many thousands have been made for use in power stations, industrial works, mines, etc., for the control of every kind of three-phase circuit of medium power up to 3,300 volts; any number of these units may be mounted side by side to form a complete switchboard, and provision can be made for the incorporation of instruments and auxiliary apparatus of the usual kinds.

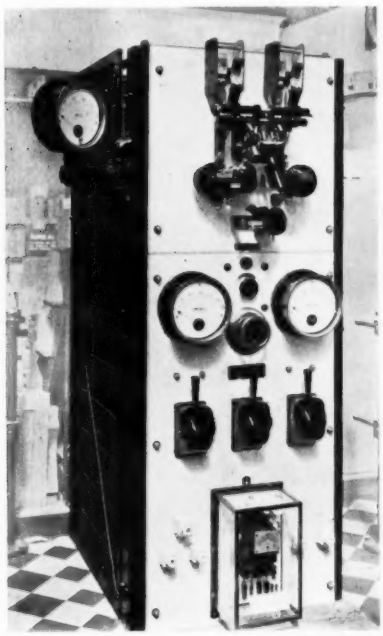


FIG. 55. SWITCHBOARD FOR THE CONTROL OF A D.C. GENERATOR.

Our extensive range of liquid-type starters for A.C. slipring motors is represented by the examples shown in Figs. 36 and 44, where two types are shown as installed in conjunction with motor drives in the Exhibition.

Amongst the varied classes of direct-current switchgear, we have selected the examples shown in Figs. 53 and 55. The former shows an air-break circuit-breaker fitted with the well-known metallic shield blow-out, and is a type developed for power house and substation use on 1,500 volt railway systems, for which purpose it is extremely efficient and substantial. Fig. 55 is a standard direct-current generator panel as used for controlling several three-wire machines, which fed the Exhibition mains; the main D.P. circuit-breaker of our SKB. class is fitted with overload and low-voltage releases, and the main switches are arranged at the back of the board and operated by the neat handle mechanisms mounted on the front. The latter is a valuable feature, particularly in a confined space, as it eliminates any live parts within normal reach; the same idea is followed by the use of our patented "Zed" cartridge fuses for the instrument circuits.

FIG. 56. EXAMPLES OF IRONCLAD SWITCHGEAR FOR THE CONTROL OF A.C. MOTORS.

FIG. 57. A 50-TON PIECE OF THE TRANSVERTER ON THE ROAD FROM PRESTON TO WEMBLEY.

THE TRANSVERTER.

For the electrical transmission of energy over a great distance, direct current has many important advantages over alternating current, due in the main to the absence of capacity and inductive effects and to the fact that for a given effective voltage a high peak voltage occurs with alternating current which is, of course, absent with direct current. These advantages have recently been set out in detail by Messrs. J. S. & W. E. Highfield,* who have put forward figures to illustrate the fact that a very great saving in cost of transmission systems can be attained by employing direct current. The transverter has been designed primarily to obtain direct current at the high voltages necessary for long distance power transmission, and while it cannot be regarded as ready for practical application at the present time, it may be of immense advantage in the not far distant future. Experiments carried out with smaller machines have given satisfactory results, and the machine included among our exhibits was one of two that had been constructed to permit of experiments being continued with units of a size that would have a direct industrial application.

The electrodynamic generation of direct current, apart from generators of the homopolar type which for obvious reasons need not be considered, necessarily involves the production of an alternating E.M.F., and its subsequent rectification by means of a commutator. At the present time electrostatic machines do not appear to offer a solution. Difficulties of insulation and commutation set a limit to the pressure for which a single direct-current generator can be built, so that M. Thury employed a number of machines connected in series, and thus obtain a solution technically satisfactory, but commercially impracticable where large amounts of power and pressures of the order of 100,000 volts are concerned.

We may consider the transverter as the equivalent of a large number of direct-current generators in series, where all the commutators have been strung on one shaft to form a single rotating unit, while the alternating E.M.F's. are

* "High-voltage Direct-current Generation and Distribution of Electrical Energy"—presented at The First World Power Conference.

produced by a group of static transformers of special form instead of in rotating armatures. It can be readily appreciated that as the transformer windings in which the E.M.F's. are produced are stationary, the simplest arrangement for commutation will be to use stationary commutators, and to rotate the brushes.

In the Transverter, the multiplication of phases is carried out in suitable secondary windings of a group of transformers,the primary windings of which are fed from a three-phase supply. The progressive phase difference between the secondaries is obtained by using a composite primary winding on each transformer core,consisting of two windings fed from two of the three phases and having their numbers of turns so proportioned as to give a resultant secondary E.M.F. with the desired phase position.

In the particular Transverter shown on our stand, there are thirty-six phases, and therefore eighteen cores; these are constructed in the form of three six-core units.

One complete set of the secondary windings corresponds to a two-pole two-circuit direct-current armature winding, and it is only necessary, therefore, to connect the junctions to consecutive commutator segments, and to rotate the commutator or brushes at synchronous speed to obtain a true unidirectional E.M.F. Obviously each transformer core may have a number of sets of exactly similar, but independent secondaries, so that we can obtain two, three or more closed windings, commutators and brushes all quite independent, and finally the brushes of all these commutators may be connected in series to give a total E.M.F. which is as many times greater than that of a single commutator, as there are commutators in series. To translate into terms of the actual machine shown, there are ten sets of exactly similar secondaries, and ten commutators.

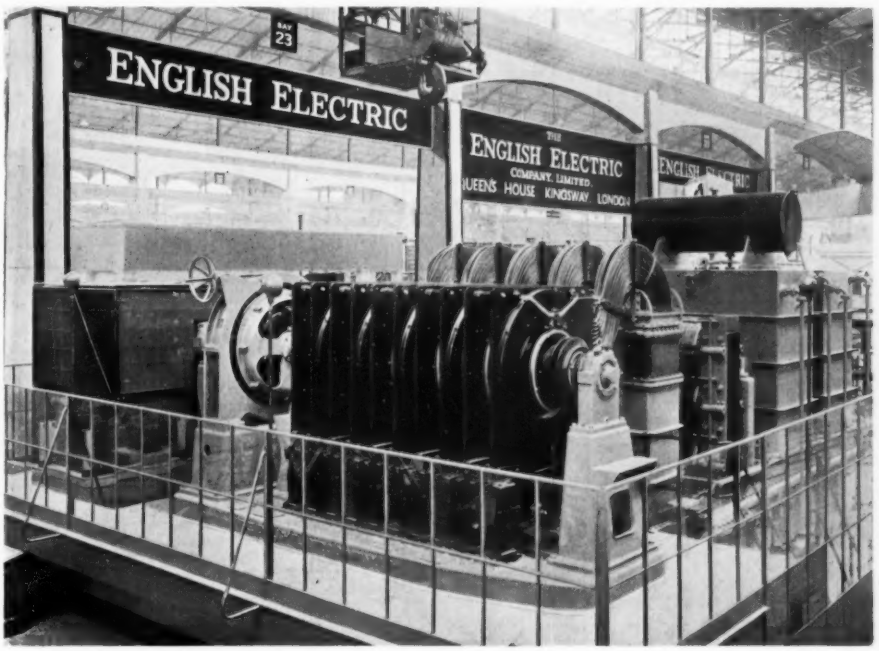


FIG. 58. GENERAL VIEW OF THE TRANSVERTER FROM THE COMMUTATOR END

It has been assumed that each commutator has the same number of segments as there are tappings from the closed series of transformer windings with which it is associated, and that the brushes are diametrically opposite and are rotated at the synchronous speed of a two-pole motor fed from the three-phase alternating-current mains. In order to reduce the speed of rotation of the brushes to half this, *i.e.*, the synchronous speed of a four-pole motor, one complete set of segments occupies only 180 deg., and it is then duplicated in the remaining 180 deg.; the two brush arms are, of course, now set at 90 deg. apart instead of being diametrical.

Dealing now with the construction of the Transverter, as exemplified by the 2,000 K.W. unit erected at the exhibition, and shown in Fig. **58**, the transformer portion of the equipment is contained in the large casing seen at one end. This casing consists of a bedplate on which the three six-core transformers are mounted, and in the bottom of which are contained the leads from the secondary coils to the commutators.

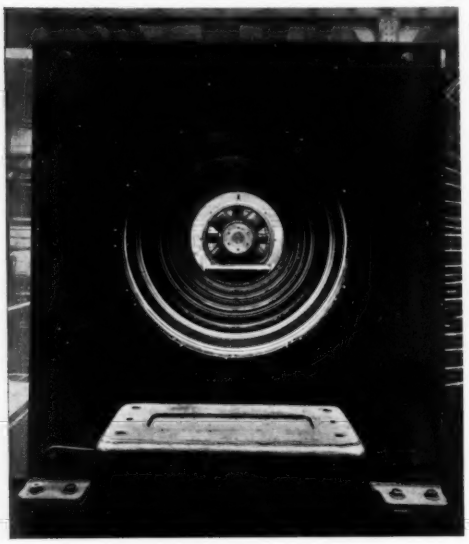


FIG. 59. VIEW THROUGH THE TEN COMMUTATORS WITH THE BRUSH-DRIVING SYNCHRONOUS MOTOR AT THE FAR END.

Each of the three transformer units is completely enclosed by a wrought-iron tank, and the joints which these make with the bedplate are thoroughly oil tight, so that the whole may be filled with oil. In Fig. **57**, we reproduce a photograph taken of the bedplate and transformer cores in course of transit from Preston Works to Wembley; in order to save time in erection, the whole of this portion was sent complete and ready for assembly.

An important detail is the orderly and symmetrical arrangement of the connections from the secondary coils to the commutator. As already mentioned, these are carried through the oil in the bedplate, where they are mounted in special racks and arranged so that the potential difference between adjacent leads is suitably limited. From the bedplate the connections are carried vertically upward through the cast iron trunks to a special sealing section, where they are jointed to the connectors which pass to the commutator segments. Each of the ten commutators consists of a heavy panel of moulded insulating material supported on insulators secured to the bedplate. The sectors, which are hard drawn copper, are moulded into the panels, and the connections to them made on the reverse side. The view in Fig. **59** gives a good idea of the construction. As we have already stated, the adoption of a fixed commutator presents many advantages, and gives the designer much greater freedom in dealing with the problems which result from the high voltage to be dealt with. The most important advantage, perhaps, is that the commutator itself can be designed to meet the electrical requirements in the highest degree without any special necessity for great mechanical strength, such as would be essential with a revolving commutator, in order to meet the mechanical stresses due to centrifugal force.

The shaft of the revolving element is of solid steel, insulated where necessary by a suitable thickness of mica, moulded on under pressure. As will be seen from Fig. 60, the insulation is of great thickness,

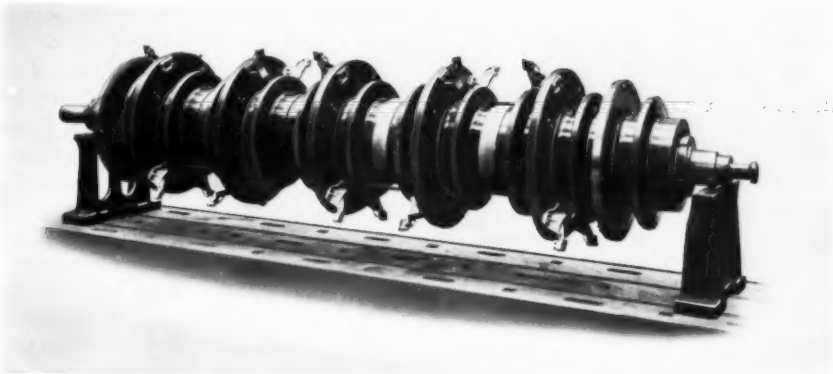


FIG. 60. THE ROTATING BRUSHGEAR, THE ONLY MOVING PART OF THE TRANSVERTER.

and is arranged with discs of Bakelised paper, from which the brush carriers are supported. The brush holders are made of a light but strong alloy, and are of ample strength and rigid design in order to avoid vibration. As already indicated, the ten pairs of brushes are connected in series, so that in order to connect the end brushes to the external circuit a slipring is necessary at each end of the brushgear system. The motor for driving the brushgear shaft can be clearly seen in Fig. 58, and is of the synchronous self-starting type provided with a heavy damping winding to ensure stability and easy starting. The separate direct-current exciter is mounted beyond the synchronous motor.

The particular unit which we exhibited is arranged for taking a three-phase supply at 50 cycles 6,600 volts and converting it to direct current at 100,000 volts. This type of plant is, however, reversible, and when direct current is fed to the commutators, it will deliver alternating current of a corresponding pressure, and at a frequency determined by the speed to which the synchronous motor is run up, by means of its exciter used temporarily as a motor. It is of interest to note that a Transverter receiving alternating current and converting it to direct current can be adjusted so as to obtain unity power factor on the input side, thereby increasing the capacity of the generating plant, as compared with the case of transmission by alternating current.

At the other end of the line, assuming another transverter is installed in connection with an alternating-current distribution system, the machine will supply any wattless current demanded by the load.

Investigations have been made with regard to the freedom of the direct current from pulsations, and it has been found that no ripples are present, and therefore, no interference with telephone lines can be caused. We show in Figs. 61 and 62, reproductions of oscillograph

FIG. 61. CURRENT WAVE OF A.C. SUPPLY TO TRANSVERTER.

FIG. 62. UNIDIRECTIONAL, NON-PULSATING VOLTAGE ON D.C. SIDE OF TRANSVERTER.

prints showing respectively the current in one phase of the supply, and the direct-current voltage. The Transverter itself deals with all the reactions between the direct current and alternating current, and there is no distortion of either the A.C. voltage or current. This result compares very favourably with some other forms of converting machinery, which either give rise to pronounced ripples in the D.C. voltage or cause distortion of the A.C. wave form.

Aircraft.

Poised above the office was a light aeroplane of the "Wren" class (see Frontispiece), a duplicate of the machine which achieved such remarkable success in the Aero Club trials at Lympne in October of last year.

This design was the outcome of an endeavour to produce a satisfactory aeroplane fitted with a low-powered engine, and thus to reduce the hitherto prohibitive cost of flying from the private owner's point of view ; the machine has been pronounced by all pilots who have flown it as one of the easiest machines to fly that they have ever handled.

The importance of this means of transit will gradually impress itself upon those in isolated parts of the Empire who have thus placed within their reach a means of travelling over wide stretches of country, where roads are inferior or non-existent, at the speed of an express train and at negligible cost.

All parts are in compliance with the Standard Safety Factors of the Air Ministry, and the machines are manufactured in the same shops and under the same conditions as those we are making for the Government, the workmanship and materials being of the very highest class.

Amongst the many special features to which attention may be directed are the arrangement of the landing wheels, and the small size and low speed of the motor. By eliminating the usual type of projecting under-carriage, and partially recessing the landing wheels into the fuselage, the head resistance is reduced, and the ease of landing greatly enhanced, especially on rough ground or bushes, etc. The fuselage bottom is reinforced so that in the event of a bad landing, it acts as an effective braking surface and this, together with the low landing speed (about 25 miles per hour) permits the machine to be brought to rest in a few yards. The maximum engine speed is only about 60 per cent. of the speed at which the same engine usually runs on the motor cycle racing track, and once in the air, half power is ample to sustain level flight ; this conservative loading and the extremely efficient cooling ensure reliability and long life. The principal dimensions are as follows : span 37 ft. ; length 24 ft.

Fig. 63. A Typical Flying Boat manufactured by the English Electric Company.

FIG. 64. ANOTHER VIEW OF A MODERN "ENGLISH ELECTRIC" FLYING BOAT.

3 ins.; height 5 ft. As the wings are readily removable, storage can be effected in a shed 25 ft. by 9 ft. by 6 ft. high; the total weight without pilot is about 230 lbs.

In the Lympne competition above referred to, one machine tied for first place in the fuel consumption tests with a figure of 87·5 miles to the gallon, while another "Wren" took second place. At one period, several laps were covered at the rate of 92 miles per gallon. In concluding this brief description, we should like to quote the following extract from *Flight*, of October 18th, 1923, referring to some remarkable "crazy" flying executed by one of the pilots :—

"This astounding machine, in spite of its diminutive engine, flies very strongly, and the controllability is all that could be asked, the machine being under perfect control even at speeds well below 30 m.p.h., and probably nearer 20 m.p.h. . . . . Altogether the 'Wren' is one of the most amazing aeroplanes ever constructed, and absolutely the only criticism that anyone could possibly level against it, is that for cross-country flying it might be found a little slow. As against that must be set the fact that the machine is as near 'fool-proof' as any aeroplane we have ever seen."

At the other end of the scale of aircraft construction, we manufacture flying boats of the largest and most modern types, and the accompanying illustrations show typical machines of this class.

Of these flying boats the "Cork" is a boat with a total displacement of 11,600 lbs., and is propelled by two "Rolls-Eagle VIII" Engines of 360 H.P. each.

It was built towards the end of the War to the order of the British Government, and when it came out, it set a new standard of performance for large flying boats, attaining a maximum speed of 106 miles an hour, about 20 miles an hour faster than any previous design of the class.

In accordance with our usual practice, the hull is built in such a manner as to render it slightly flexible, the main construction consisting of a series of rock elm hoops connected by longitudinal members to which the skin is attached.

This construction has proved very successful in practice; in fact N.86, the first of the "Cork" boats to be built, is still in service and flying well after six years' hard work.

In Figs. 63 and 64, views are shown of the development of the "Cork," known as the "Kingston," which has been designed and built by us for the Air Ministry, but as the Air Ministry does not permit details of this machine to be published, particulars cannot be given of the many improvements incorporated in its design.

FIG. 1. ARTHUR'S PASS TUNNEL ELECTRIFICATION, NEW ZEALAND. 1,500-VOLT LOCOMOTIVE HAULING FREIGHT TRAIN IN SEVERE WINTER WEATHER.

Arthur's Pass Tunnel Electrification, New Zealand.

FIG. 2. THE GENERATING STATION AT OTIRA.

In previous issues of this Journal we have given a few particulars of the contract which the English Electric Company secured for electrifying the Arthur's Pass Section of the Midland line of the New Zealand Government Railways.

The contract was successfully completed last year, and the line was officially opened by the Prime Minister of New Zealand on August 4th, 1923, since when it has been in regular operation. A fuller description of this, in some respects, unique undertaking may, therefore, be found of interest, and in order that its importance may be appreciated, we may to advantage review briefly the circumstances which led to its inception.

The commercial and industrial development of any new country is always closely identified with its geographical and physical characteristics. A district particularly favourable to certain industries may remain undeveloped or its development be retarded for generations if it lacks convenient access to suitable markets for the disposal of its products.

The history of the South Island of New Zealand furnishes a marked example of this principle. The Island is traversed from north to south by an almost impassable range of snow-capped mountains, known as the Southern Alps, branching out fanwise at each end to the coast, and so absolutely isolating from each other the two important Provinces of Canterbury and Westland. These two provinces, whilst differing widely as regards climate, physical characteristics and extent of development, are in many respects complementary,

each producing or possessing what the other lacks, to a remarkable degree. Given a means of cheap transport between them, each would provide a natural market for the products of the other. Canterbury, the chief province of the South Island, in which is situated Christchurch, the capital, and the thriving port of Lyttelton, is chiefly engaged in sheep rearing and exports frozen mutton and wool, but is in need of a home market for its food products and manufactures, the cheap power now available from the Lake Coleridge Hydro-Electric Plant having made possible its great development as a manufacturing district.

Westland, originally opened up by the discovery of gold there in the 'sixties, has great wealth in timber and is also believed to be rich in minerals. Already coal is mined to a considerable extent. Agriculturally, cattle rearing and dairy produce are its industries. Apart from the ready home market for most of these commodities which Canterbury should provide, Westland needs access to the freezing plants and ports of the latter for its export trade. The absence of such access has been a constant handicap to its development.

Until the new line was opened, any interchange of commodities involved a sea journey of some 400 miles with costly handling at each end. Moreover, the chief port of Westland, Greymouth, has a bar harbour which added another complication, both for coastwise and export traffic.

The only direct inland means of communication existing prior to the opening of the railway through the tunnel last year, was the coach road over Arthur's Pass, above the head waters of the Waimakariri River, about 3,000 feet above sea level. The Pass was discovered in 1864 by Mr. Arthur W. Dobson, a young Civil Engineer employed by the Provincial Government of Canterbury to carry out a survey on the western side of the Southern Alps, and was named after him. The coach road was constructed a few years subsequently. This route was quite unsuitable for transport of goods in any quantity. The journey over the Pass in bad weather was extremely hazardous, involving the fording of several swift rivers. The distance between the sites of the present stations at Otira and Arthur's Pass over the Pass was about 13 miles, and took the coach four hours even in good weather. The electric trains through the tunnel now traverse the distance between these points in from 20 to 30 minutes.

In a country with a total population which is even now under 1½ millions (both Islands) it can be well understood that the problem of railway construction with its heavy capital expenditure has always taken a prominent place in the national politics.

It is not possible in a short article such as this to give even an outline of the railway history of the colony. Suffice it to say that ever since the first railway was commenced in 1860, the proposal for a line giving direct communication between Westland and Canterbury has been more or less prominently before the public.

The two great difficulties were the provision of the necessary capital and the finding of a suitable means of negotiating the intervening mountain range.

Short portions of line were constructed between several places *en route*, on both sides, from time to time, but no real attempt was made at a comprehensive scheme until about 1886, when the Midland Railway Company was formed. Although this Company carried on work for nine years, it only managed to construct and put into operation about 35 out of approximately 235 miles of line undertaken, and then sought to be released from its contract, chiefly due to unexpected difficulties encountered by reason of the rough country to be traversed by the remainder of the line. The Government thereupon took over the work, releasing the Company from its obligations on agreed terms.

It was not, however, until towards the end of last century that the problem of the link across

the mountains became acute. A variety of proposals had been put forward from time to time with a view to avoiding the huge capital expenditure (and in early days the engineering objections) involved in the construction of a tunnel. Sundry circuitous routes *via* the Northern Province of Nelson and the Southern Province of Otago had been mooted, each being dropped in turn. A mountain railway with a gradient of 1 in 15 on the Fell system over Arthur's Pass had also been considered.

After several surveys it was decided in 1900 that the only sound solution was a summit tunnel under Arthur's Pass, but it was not until 1907 that a contract for the tunnel was actually placed. In April, 1908, work was commenced at the Otira end, and in July, 1909, at the Arthur's Pass end. The tunnel is entirely in solid rock except for a few hundred feet at the portals, and it is lined throughout. The side walls and footings are of mass concrete and the arch is formed of concrete blocks. The situation of the tunnel and lack of means of transport introduced extraordinary difficulties in bringing the necessary material to site, and after spending nearly half the contract figure on plant and material and making great efforts to proceed with the work, the contractors found that they could not possibly finish it for the contract price. After lengthy negotiations, the Government agreed in 1912 to release them from their contract, and coming to the conclusion that no private contractor would again face the task, decided that the Public Works Department should carry it on. Reasonable progress was made until the War broke out, after which it was very slow, due to the difficulty of obtaining labour and materials, but work was continued in spite of these difficulties, and in August, 1918, the final barrier between the two ends of the tunnel was pierced.

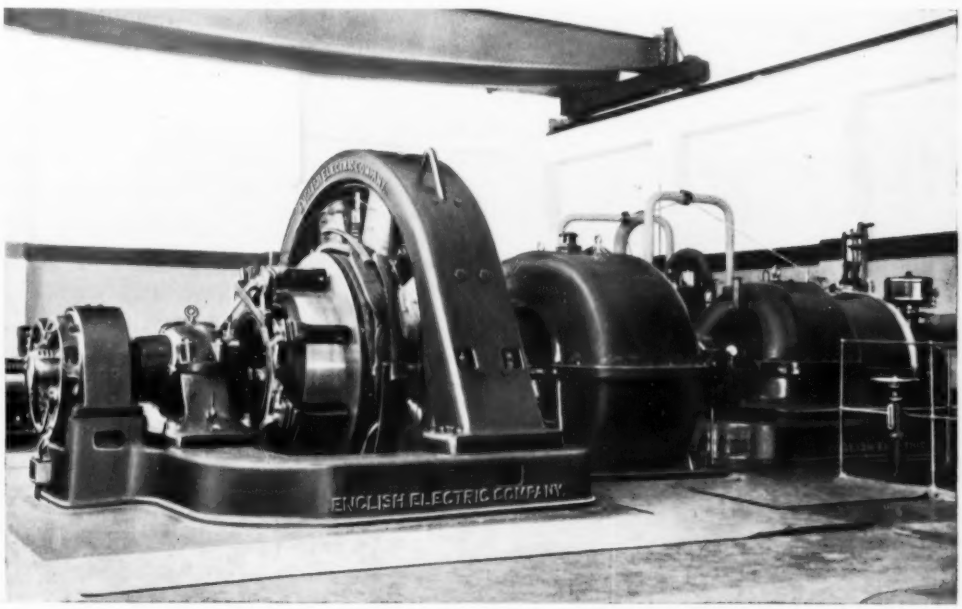


FIG. 3. ONE OF THE 1,200 KW., 1,650-VOLT, DIRECT-CURRENT STEAM TURBO-GENERATOR SETS.

The exact length of the tunnel is 5 miles 554 yards, perfectly straight, with a grade of 1 in 33, rising from about 1,585 feet above mean sea level at the western end to a height of 2,435 feet at the eastern end, which is, therefore, only a few hundred feet below the summit of the pass, the total rise being 850 feet. The tunnel is the seventh longest tunnel in the world and is the longest in the British Empire.

In view of the steep gradient of 1 in 33 and the length of the tunnel, no other system than electric haulage was seriously considered. The question as to how far to electrify the line on either side of the tunnel, however, was one which greatly exercised the minds of the authorities, and alternative schemes were prepared for the electrification of the whole mountain division from Jackson's to Springfield, and, alternatively, from Jackson's to Cass, and from Otira to Arthur's Pass. It was decided, finally, to limit the application of electric working to the Otira-Arthur's Pass section as a first instalment, in view of the need of keeping down capital expenditure, and as a wider extension of the electrification was bound up with a corresponding extension of the Lake Coleridge Power Plant. Moreover, it was felt desirable, as the electrification was in some degree an experiment, that it should be carried out at first on a small scale, with a view to obtaining a nucleus of skilled operatives in readiness for the eventual larger scheme.

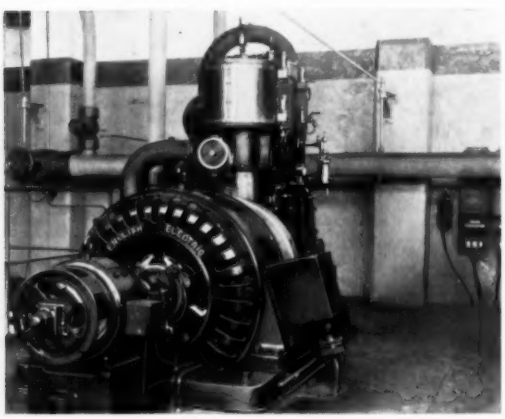


FIG. 4. ONE OF THE 125 KVA. AUXILIARY GENERATING SETS FOR THREE-PHASE SUPPLY AT 2,200 VOLTS, 50 CYCLES.

The length of the section which it was decided to electrify covers a total route length of 8 miles 32 chains, of which the tunnel itself occupies 5 miles 25 chains, leaving 3 miles 7 chains of route outside the tunnel, in addition to which there are nearly 5 miles of sidings.

The elevation at Otira Station is 1,248 feet, and at Arthur's Pass Station 2,435 feet, which is also the highest elevation in the division, making a difference in level between the two ends of the electrified line of 1,187 feet, an average gradient of 1 in 37¼. The ruling gradient of 1 in 33 is 6 miles 51 chains in length, including the tunnel.

The track through the tunnel is a single line of 3 ft. 6 in. gauge, which is the standard gauge of the New Zealand Government Railways.

The system of electrification selected was 1,500 volts direct current with overhead contact. It may be mentioned that this is in line with modern tendencies in railway electrification in other countries. The same system and voltage have been adopted as standard both for the English and French Railways, and are in use on the Melbourne Suburban Railways in Australia and the Imperial Government Railways in Japan.

The traffic conditions specified for the electrified section were 20,698 ton miles for freight and 2,950 ton miles for passenger trains per day, this, which includes locomotives, making a total of 23,648 ton miles per day, or 27,195 ton miles, allowing 15 per cent. for shunting operations. This means a total train movement of 8,484,840 ton miles per annum over the electrified section. This involves approximately 1,000 tons gross of freight cars per day from west to east, and 700 tons per day from east to west, carried in four trains each way, and in

addition, one six coach passenger train each way per day.

Power Station.

Although eventually the electrical energy for operating the railway may be taken from the Government Hydro-Electric Plant at Lake Coleridge, particularly if the contemplated extensions mature, as the transmission lines from that source of supply do not at present run conveniently near the electrified section of the line, it was decided to install a steam station at Otira. This station, which is shown in Fig. 2, was built by the Public Works Department, and equipped with three Babcock and Wilcox boilers to supply steam at a pressure of 160 lbs. per sq. in. at the turbine stop valves, superheated to 500° F.

The Electric Generating and Auxiliary Plant supplied by the English Electric Company under their contract comprises the following :—

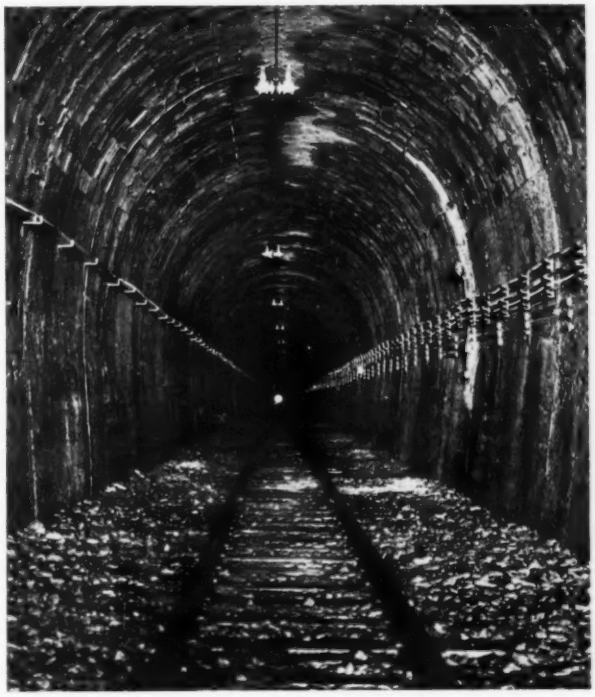


Fig. 5. Interior of Tunnel showing Overhead Line and Method of Supporting Cables.

(*a*) Two Main Generating Units, each consisting of an "English Electric" horizontal impulse type steam turbine, running at 3,000 r.p.m. and driving through double helical reduction gearing a separately excited D.C. generator of 1,200 KW., normal rating, 1,650 volts, 450 r.p.m. Overload capacity—25 per cent. for two hours, 50 per cent. for 30 minutes and 100 per cent. for 5 minutes. Each generator is complete with its own direct-coupled exciter of 15 KW. at 110 volts. The reduction gearing is provided with a system of forced lubrication. One of these units is illustrated in Fig. 3.

(*b*) Two Surface Condensers to maintain a 29 in. vacuum when supplied with 2,000 gallons of water per minute at 50° F., and to deal with 22,200 lbs. of steam per hour. Cooling water is obtained from a reservoir suitably located so that it supplies the condensers by gravity without the necessity for any pumping. Motor-driven extraction pumps are provided for the condensate.

(*c*) Two Auxiliary Generating Sets (see Fig. 4) for supplying current for lighting the tunnel, stations, power house, sidings, etc., each consisting of a compound high speed steam engine by Browett Lindley & Co. direct-coupled to a 125 KVA. 3-phase alternator, 2,200 volts, 50 cycles, at 500 r.p.m. with direct-coupled exciter. Overload capacity—25 per cent. for two hours and 50 per cent. momentarily.

(*d*) One Surface Condenser to deal with the exhaust from either of the above lighting

sets, and to maintain a 26 in. vacuum when supplied with 210 gallons of cooling water per minute at 50° F. and to deal with 3,770 lbs. of steam per hour.

(*e*) One Negative Booster Set consisting of a 1,650-volt D.C. motor driving a 0/125 KW. booster to give 0 to 225 volts, and provided with its own direct-coupled exciter for the motor. Overload capacity —25 per cent. for 2 hours, 50 per cent. for 30 minutes and 100 per cent. momentarily.

(*f*) One Battery Booster for charging the battery locomotive and auxiliary batteries of the main locomotives, consisting of a 3-phase induction motor, 400 volts, direct-coupled to two D.C. generators, rated at 40 KW. 500/600 volts and 5 KW. 110/170 volts, on normal full load. Overload capacity— 25 per cent. for 2 hours, 50 per cent. for 30 minutes and 100 per cent. momentarily.

(*g*) Two 3-phase Transformers for station lighting and supplying station auxiliaries, 100 KVA. (80 KW. at ·8 P.F.), primary 2,200 volts, secondary 400 volts with neutral brought out to give 230 volts for lighting.

(*h*) The necessary main and auxiliary switchgear for controlling :—

(I) The 1,650-volt D.C. supply from the main generators.
This is of the mechanically operated, remote controlled type, the switches and other live apparatus being contained in stonework cubicles in an annexe to the engine room.

(II) The 2,200-volt, 3-phase A.C. supply from the auxiliary generators.
For this purpose "English Electric" standard SXA, ironclad draw-out type switch pillars are employed.

(III) The 400-volt, 3-phase, A.C. supply from the secondaries of the station transformers.

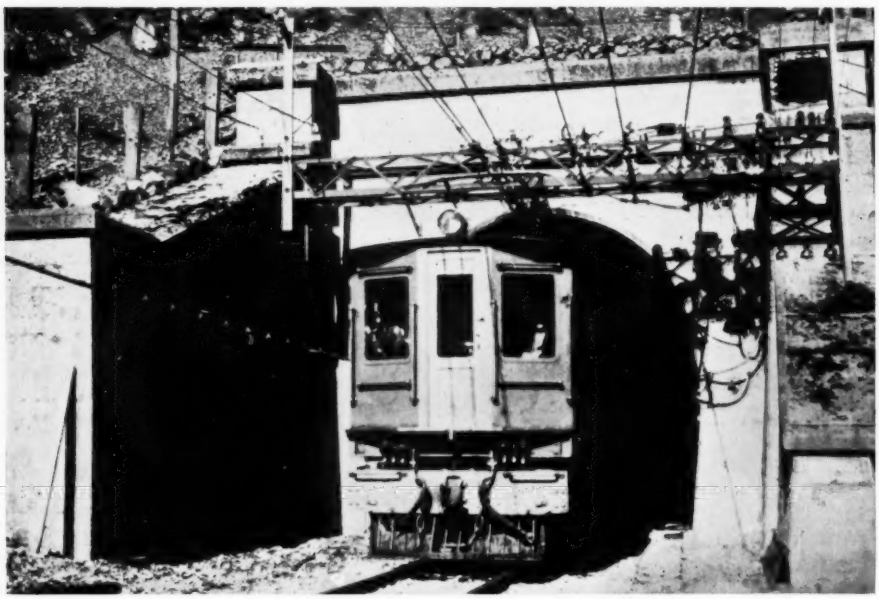


FIG. 6. OTIRA PORTAL OF TUNNEL.

In this case "English Electric" standard S.W. type, air-break, ironclad switches and standard bus-bar chambers are used, built up on standard supporting brackets to form a complete ironclad switchboard.

(*j*) One 10-ton Overhead Travelling Crane, electrically operated.

FIG. 7. TRAIN ENTERING ARTHUR'S PASS STATION. THIS SHOWS THE BRACED CANTILEVER CATENARY SUSPENSION SPANNING BOTH TRACKS.

WORKSHOP.

The main power house building includes a workshop for dealing with repairs and overhauling of the plant. This is equipped with :—

1—15-ton Overhead Travelling Crane, electrically operated.

1—Armature Turning Lathe.

1—Banding Reel and Brake for banding armatures.

The usual lathes, drilling machines, grinders, smith's outfit, etc.

RUNNING SHEDS.

The Government have also provided, adjacent to the power house, running sheds for the locomotives with inspection pits and all up-to-date facilities. A separate shed is provided for the battery locomotive.

The English Electric Co.'s contract included also the following sections :—

CONTACT LINE AND OVERHEAD CONSTRUCTION.

The overhead work in the open is of the double catenary type. In the Otira Station area the catenary wires are of 7/12 S.W.G. galvanised steel, stranded, but on the main line they are of copper, each 37/13 S.W.G. stranded, ·25 sq. in. section. The contact wire is 6/0 S.W.G. grooved and suspended every 15 feet to the catenary by copper wire droppers. Every 300 feet the catenary wires are bonded to the contact wire by a 37/15 S.W.G. copper bond. In the tunnel a single catenary of ·5 square inch (61/·104 in.) stranded copper is used supported every 90 feet. In the open the overhead work is carried on wooden poles of Australian iron bark, 50 yards apart on straight runs. The insulators are supported on simple angle iron cantilever brackets above runs of single track. In stations a more complicated lattice cantilever is used, and on sidings where a number of tracks are embraced, a girder of the trussed beam type is used, supported by a wooden pole at each end, the insulators being carried on the top member.

FEEDERS AND CABLES.

A positive feeder of ·5 sq. in. stranded copper is used, bonded every 300 feet to the catenary

in the open and every half mile in the tunnel. This feeder is bare in the open and lead-covered in the tunnel. The negative feeder connected to the negative booster is 1 sq. in. in section, consisting, outside the tunnel, of two bare cables, ·5 sq. in. each, and of one lead-covered cable in the tunnel. This feeder ends 5·2 miles from the power station where it is bonded to the rails. The bare portions of both positive and negative feeders are carried on steel cross arms fitted with insulators and attached to the poles carrying the overhead contact line. A pilot wire 7/18's S.W.G. is carried from the power station to Arthur's Pass Station for the purpose of measuring the rail drop. Two stranded copper bonds 4/0 B. & S. are used at each rail joint and cross bonds between adjacent tracks at every structure. These are connected to the bracket arms of poles or to the cross girders for earthing purposes. All metal work of insulators and pins, etc., is earthed to the rail both inside and outside the tunnel.

Tunnel Lighting.

The tunnel is lighted throughout its length. Current from the 2,200-volt, 3-phase lighting generators is conveyed to the tunnel entrance by means of 19/·064 in. bare copper conductors carried on the poles supporting the overhead contact line. At this point two separate 3-phase circuits are taken off, each protected by three single-pole fuses and a triple-pole isolating switch. These separate circuits consist of 3-core paper-insulated lead-covered cables. One (the main circuit), a 3-core, ·025 sq. in. cable, feeds six single-phase transformers, each 2½ KVA. 2,200/230 volts, suitably spaced along the length of the tunnel and, at the far end, a 3-phase 25 KVA. 2,000/400-volt transformer which serves Arthur's Pass Yard and Station.

The other (or auxiliary) circuit, a 3-core, ·003 sq. in. cable feeds three single-phase transformers, each 2½ KVA. 2,200/230 volts.

Each of the six transformers connected to the main circuit feeds approximately 4,400 ft. of L.T. cable along the tunnel, *i.e.*, 2,200 ft. on each side. 60-watt lamps, in bulkhead fittings, are spaced at approximately 165 ft. intervals along the L.T. cable. All the lamps fed from this main circuit are intended to burn continuously. Plug sockets with watertight switches are also provided at intervals for attaching portable lamps for the use of repair gangs, etc.

The three transformers on the auxiliary circuit supply similar lamps interspaced with those in the main circuit.

The auxiliary circuit is only for use in emergency or where extra lighting is required for inspection purposes, etc.

Main Line Locomotives.

Although both freight and passenger traffic had to be provided for, it was decided to employ one type of locomotive only.

This policy has obvious advantages from the standpoints of operation, maintenance and overhaul, particularly as the total number of locomotives on a line such as this, is not likely ever to be great.

The specified maximum trailing loads were 280 tons for freight and 138 tons for passenger traffic.

For the freight service the operating schedule allowed 34 minutes between station and station in either direction, which corresponds to an average speed of 15·35 m.p.h.

For the passenger service the time allowed from Otira to Arthur's Pass, *i.e.*, on the up gradient, was 30 minutes, whilst in the reverse direction, *i.e.*, down hill, the time allowed was 21 minutes. These times correspond to average speeds of 17·35 and 24·8 m.p.h. respectively.

These conditions are met by using one locomotive for hauling passenger trains and two, connected in multiple unit (requiring only a single crew), for freight trains.

The locomotives are five in number, all identical. Wheel arrangement 0-4-4-0. Gauge 3 ft. 6 in.

They are of the articulated type, the draft and buffing gear being attached to the bogies. This

arrangement avoids subjecting the cab or underframe to any of the driving stresses. The cab is of the box pattern.

Weight—50 tons.

Weight per driving axle—12½ tons.

Each driving axle carries a 750-volt motor of 170 B.H.P. on the one-hour rating. The motors are connected in pairs in permanent series, each operating at 750 volts but insulated, of course, for 1,500 volts. They are forced ventilated. The driving gear is of the single reduction spur type, having a gear ratio of 15/68. This gives an acceleration of 0·5 ft. per sec. per sec. on a 3·03 per cent. grade, with a trailing load of 140 tons gross.

The control equipment is of the "English Electric" Camshaft all-electric type, arranged for either single or multiple unit operation with a single locomotive crew.

This form of control equipment has been described in previous issues of the Journal. Amongst its features are its extreme simplicity and the avoidance of complicated interlocks, due to the fact that the sequence of operation of the contactors is mechanically defined by the cams. Moreover, it does not require for its maintenance the skilled mechanics which are necessary to maintain the electro-pneumatic type of control. The camshaft is rotated by means of a small electric motor which is instantaneously brought to rest at the required points by the short circuiting of its armature by a relay operated by a position regulator. With the exception of two contactors which break a small equalising current during transition, none of the contactors have to break current. This operation is taken care of by the line breakers specially designed for rupturing heavy currents.

The operating current for the control is obtained either from a rotary transformer, or from an emergency storage battery, with which each locomotive is equipped, the voltage being 120.

The locomotives are furnished with four distinct brake equipments, considered necessary in view of the steep gradient :—

1. Westinghouse air brake—automatic (operating the brakes on the locomotives and cars).
2. Westinghouse air brake—non-automatic (operating the locomotive brakes alone).
3. Hand brake, independent of Westinghouse brake rigging.
4. Rheostatic electric brake, independent of current from the overhead contact line.

Battery Locomotive.

For maintenance of the overhead line and general inspection purposes a storage battery locomotive has been provided.

As will be seen from Fig. 10, this is of the

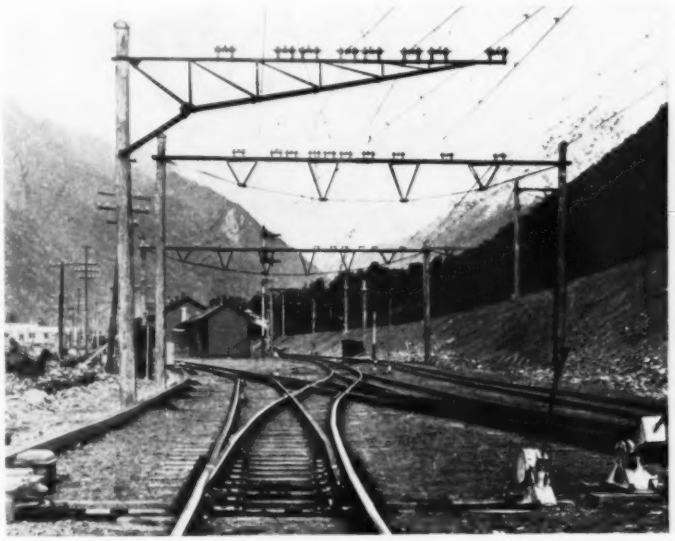


Fig. 8. Track and Overhead Work showing two methods of Catenary Suspension.

FIG. 9. FREIGHT TRAIN ON EMBANKMENT SHOWING SINGLE CANTILEVER CATENARY SUSPENSION USED OVER STRAIGHT SINGLE TRACK.

FIG. 10. LOCOMOTIVE ON CURVE NEAR OTIRA PORTAL OF TUNNEL, ROLLESTON RIVER BRIDGE IN BACKGROUND. THIS VIEW SHOWS THE MOUNTAINOUS CHARACTER OF THE COUNTRY.

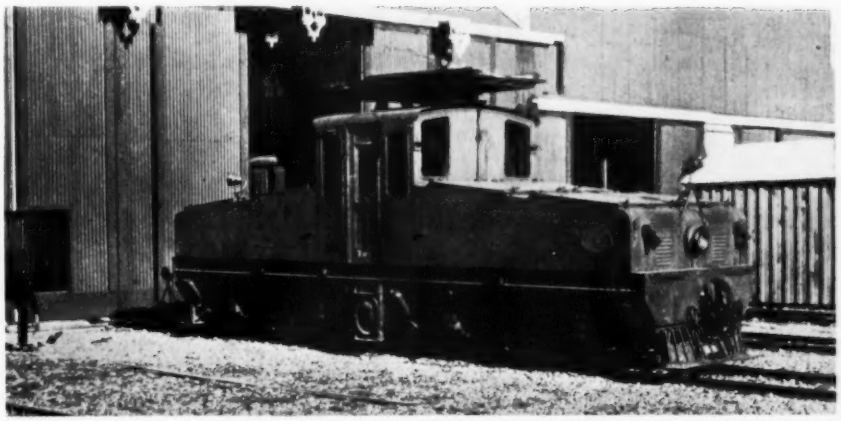


FIG. 11. BATTERY LOCOMOTIVE OUTSIDE RUNNING SHEDS. THE INSPECTION PLATFORM IS LOWERED.

central cab type with sloping ends. Wheel arrangement 0-4-4-0. Gauge, 3 ft. 6 in.

The battery, which is of the "Ironclad Exide" type manufactured by the Chloride Electrical Storage Co., is in two halves, one half carried on the locomotive proper and the other half in a separate tender. Each half of the battery can be used separately and they are interchangeable.

There is a 50 B.H.P. (1 hour rating) 440-volt motor on each of the four driving axles, the latter being driven through single reduction gearing having a ratio of 15/83.

The controller is of the English Electric Company's standard D.K. traction type with metallic shield blow-out with additional notches for controlling the magnetic track brakes.

The locomotive is equipped with a Westinghouse air brake, a magnetic track brake and a powerful hand brake.

There is an inspection platform on the top of the cab, which can be raised or lowered by means of suitable gearing, and is provided with collapsible guard railing.

The contract load is 40 tons uphill at 8·5 m.p.h.

It may be mentioned that the electrifying of the line was carried out under very trying weather conditions. During the winter extremely heavy snowfalls occurred in the neighbourhood of the Pass, and temperatures as low as −8° F. have been recorded on several occasions.

Since the official opening of the line a regular service of goods and passenger trains has been maintained through the tunnel. Up to the end of July, 1924, the locomotives had run an average of over 10,000 miles each, and reports to hand of inspections and overhauls have shown a very satisfactory condition of every part of the locomotives and equipment after this service. Already the full specified traffic has very nearly been reached, and the results of the twelve months' working show that the locomotives and other portions of the plant at present installed will easily deal with traffic up to the limits specified.

As regards costs of working, no figures are yet available, but in so far as these are affected by the performance and maintenance of the electrical plant and locomotives, there is no reason to expect that the Government Engineers' estimated costs will be exceeded. Indeed if successful operation of the portion of the line so far electrified is to be regarded as a determining factor in the extension of electrification to other portions of the system, the prospect would appear to be distinctly favourable to the carrying out of such extensions in the not far distant future, particularly as the Lake Coleridge plant extension is now being actively considered.

New Double Drive for a Reversing Two-High Rolling Mill.

The standard drive adopted for the present-day Two-High Reversing Mill is to make use of a reversing motor coupled to the lower of two pinions, with a 1 : 1 ratio, mounted in a pinion housing. The two pinion shafts are extended through the housing on the mill side and are coupled respectively to the bottom and top rolls by long leading-in spindles. By this means the top and bottom rolls are simultaneously driven, and a large amount of power is transmitted through the pinions which are, as a rule, of the double-helical machine-cut type running in oil. Not only are these pinions extremely expensive owing to their large size, but there are a number of disadvantages connected with their use which, up to the present, have had to be faced owing to the lack of an alternative form of drive whereby their use could be discontinued.

Through the courtesy of Messrs. Pease and Partners, who kindly allowed their 36-in. Reversing Section Mill to be used for the purpose, a test was recently carried out to prove the value of a patent taken out by The English Electric Company whereby the use of the pinions can be eliminated.

In Fig. 1 is shown the normal method of drive of a reversing mill with a double-armature mill motor at one end driving the two rolls through pinions.

The alternative arrangement now suggested is shown in Fig. 2, in which each of the two halves of the double-armature machine is attached direct to one of the rolls without the interposition of any gearing.

The reversing mill at the Skinningrove Works of Messrs. Pease & Partners consists of three stands of rolls—cogging, roughing and finishing—all in line, and under normal conditions the cogging rolls are driven by a double-armature of 12,000 H.P. peak at one end and the roughing and finishing rolls driven by a three-armature 19,000 H.P. peak from the other end. As all the rolls are in line it was a comparatively simple matter to connect the three top rolls together and to drive these from the cogging mill motor and to couple the three bottom rolls together and to the finishing mill motor.

By using one of the flywheel sets to supply power to both motors the conditions for the new drive were reproduced, the arrangement of the mill and the drives being shown diagrammatically in Fig. 3, from which it will be seen that there is no mechanical connection between the top and bottom line of rolls.

Under mill conditions as described above a number of ingots weighing 50 cwts. and about 19 in. square were successfully rolled down to flat bars $18\frac{3}{16}$ in. wide by $\frac{3}{4}$ in. thick, and the operation of the plant appeared to be identical with the conditions obtaining when the pinions are in action, with the exception that a difficulty which had occurred during the morning under normal operation, owing to the bar bending on the edging pass, was entirely absent under the new conditions.

The result of the test satisfied the engineers present that the new form of drive from the operation point of view equalled that of the pinion drive, thus giving full weight to the advantages detailed below.

The suggestion of coupling a motor to each roll independently is not new, but the inherent difficulty in the case of a reversing mill lies in the fact that it is essential that the two rolls shall reverse simultaneously whilst retaining the property of setting themselves to the correct speed to give equal peripheral speeds on the roll surfaces. This latter condition is obtained by connecting the motor armatures in series, as

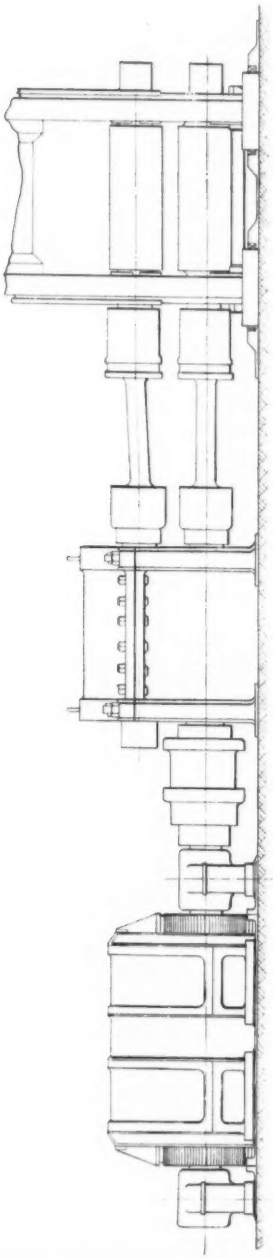


FIG. 1. NORMAL METHOD OF DRIVING REVERSING MILL BY DOUBLE ARMATURE MACHINES AND GEARING.

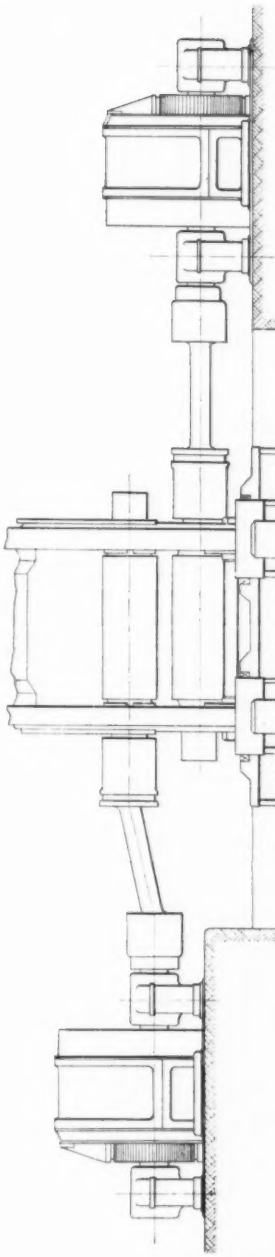


FIG. 2. PROPOSED NEW METHOD OF DRIVING REVERSING MILL WITH TWO SINGLE ARMATURE MACHINES WITHOUT GEARING.

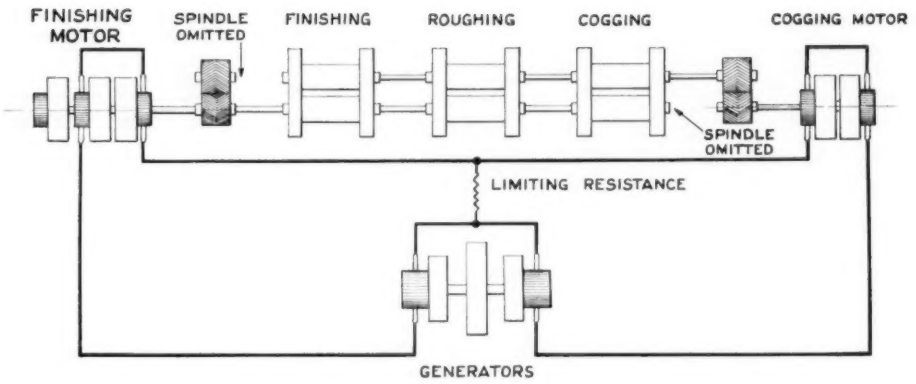


FIG. 3. ARRANGEMENT OF REVERSING MILL AND DRIVES USED IN TESTS OF PROPOSED NEW DOUBLE DRIVE.

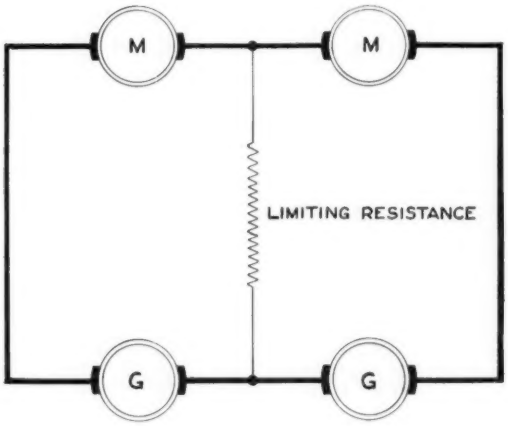


FIG. 4. ARRANGEMENT OF TIE CONNECTION TO ENSURE SIMULTANEOUS REVERSAL OF BOTH MOTORS.

with this method of connection the applied voltage divides itself between the two armatures in such a manner that the peripheral speed of the rolls remains equal in spite of any difference in diameter of the rolls themselves. The series connection by itself would permit of one roll, during the reversal and starting up period, to revolve whilst the second roll remains stationary, which would militate against the introduction of the metal into the rolls and give unsatisfactory rolling conditions.

To overcome this, a number of devices are possible but the simplest and best method is to adopt an electrical shunt connection, as indicated in Fig. 4, corresponding to an ordinary three-wire connection, but embodying a resistance of such value that, whilst on light-load the two individual motors can be considered in parallel, yet when the load comes on, the series connection shall be predominant and thus retain the speed setting characteristic mentioned above. This result was most satisfactorily obtained during the test and the reversal of the two sets of rolls took place simultaneously, whilst no interference was noticeable in the speed setting of the two pairs of rolls during periods of rolling.

The advantages inherent to the new method of drive are :—

(1) A saving in capital cost of the plant due to the elimination of the pinions and pinion housing.
(2) Avoidance of upkeep charges on pinions and pinion housing.
(3) Reduced power consumption by avoidance of frictional losses in pinions and bearings and losses by slipping of the rolls on the surface of the metal.
(4) Better rolling on account of correct setting of the peripheral speed of the rolls to the speed of the metal.
(5) The possibility of varying at will the torque at the surface of either roll.

The advantages enumerated under (1) and (2) are obvious, and that under (3) may be very great. Consider the case of a Plate Mill in which a roughness having been discovered in one of the rolls, the surface is dressed up, thus leaving it somewhat smaller in diameter than the other roll, a case which occurs frequently in practice.

Under normal conditions the speed of the rolls is tied together by the pinions so that the peripheral speed of the one roll is faster than that of the other. Under such circumstances the metal between the rolls must set itself to a mean speed with consequent slipping between the metal and the rolls, producing heavy friction losses and great strains on the pinions and leading-in spindles, or alternatively the top surface of the plate will be rolled out either faster or slower than the bottom surface of the plate, which causes bending of the piece either downwards or upwards, which introduces heavy shocks on the mill floors and difficulties in handling. Automatic setting of the roll speeds to give equal peripheral speeds is consequently of prime importance.

The advantage mentioned under (4) follows from the avoidance of slipping between roll and metal.

Finally, the torque adjustment of the top or bottom roll mentioned under (5), may prove of great service when rolling certain sections which, in a particular groove, may from the design of the groove tend to follow one of the rolls round instead of coming out straight. In such a case, by increasing or decreasing the torque of one of the rolls, which can be done quite simply by the operation of a shunt regulator, a straight piece will result.

The opportunity of testing out such a departure from present practice on an existing plant is very rare, and the kindness of Messrs. Pease and Partners in permitting such an experiment to be made with their plant, and the assistance afforded by them in the use of their men and material, cannot be too highly appreciated.

The results obtained fully justified the confidence felt that the new drive would be entirely successful.

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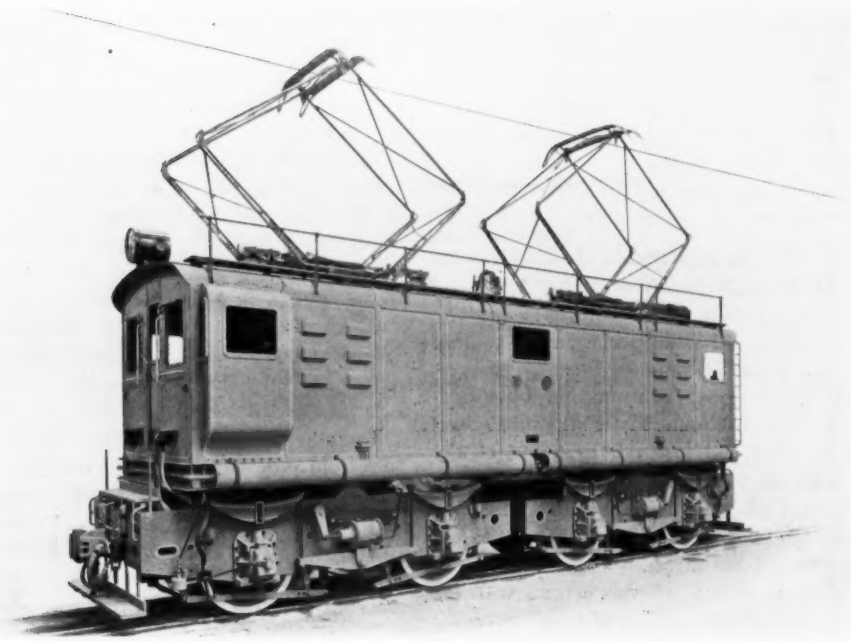

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